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THESIS

CANNIBALIZATION OF THE F-14 AND S-3A AIRCRAFT:
A VIABLE LOGISTIC ALTERNATIVE

by

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This thesis presents the results of an analysis of cannibalization and its effects on the F-14A and S-3A aircraft. The analysis includes cannibalization measurement methodologies, reasons why squadrons cannibalize, a comparison of fleet cannibalization activity and alternatives to cannibalization. Cannibalization is shown not to be a maintenance practice to be avoided at all cost, but rather a viable cost effective

alternative to logistic system failures. Additionally, material issue response delays rather than material shortages were found to lead to increased cannibalization.

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Cannibalization of the F-14A and S-3A Aircraft: A Viable Logistic Alternative

by

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Submitted in partial fullfillment of the
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ABSTRACT

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I. INTRODUCTION

A. BACKGROUND

Cannibalization can be simply defined as the removal of a component from one aircraft for use in restoring another aircraft to a flyable status. For example, if aircraft number one is not ready for flight because it needs a replacement radio and aircraft number two has a functioning radio, then cannibalization is merely removing the radio from the second aircraft and installing it in the first.

On 29 August 1978 the Chief of Naval Operations directed all aircraft squadrons to reduce their level of cannibalization by 20 percent. In this connection, the Chief of Naval Operations expressed great concern over the wasted aircraft maintenance manhours that were taking place every time a maintenance technician cannibalized a needed component [1].

These wasted manhours amounted to double work in that every time cannibalization takes place two component removals and two component installation are necessary. At the time of this direction by the Chief of Naval Operations, as well as since that time, the F-14A and S-3A aircraft have had the highest levels of cannibalization ever achieved by any naval aircraft. No matter what cannibalization measurement methodology is used, the F-14A and S-3A aircraft are number one and number two navywide. In fact, the F-14A

and S-3A aircraft are cannibalized at twice the overall navy-wide cannibalization rate. Because of this they were chosen to be the subjects of this cannibalization study.

B. THESIS OBJECTIVE

This thesis has four major objectives as they relate to the Chief of Naval Operations goal of reducing cannibalization. They are:

1. To research cannibalization measurement methodology. Since reducing cannibalization by 20 percent is the major objective of the Chief of Naval Operations, any study of cannibalization would be incomplete if it did not include an indepth analysis of how cannibalization is or can be measured.

2. To research why squadrons cannibalize. By knowing why aircraft squadrons cannibalize, major policy makers should be better able to assist squadrons in cannibalization reduction.

3. To present a comparison of cannibalization in the Atlantic and Pacific Fleets. By knowing how to measure cannibalization and why squadrons cannibalize, the Chief of Naval Operations can establish a baseline to compare the present levels of cannibalization to future levels. Since the Commander Naval Air Forces U.S. Atlantic Fleet and the Commander Naval Air Forces U.S. Pacific Fleet are responsible for cannibalization reduction and monitoring

in their respective fleets, a study of cannibalization would be incomplete without a comparison between the two.

4. To determine if cannibalization is an evil or a viable logistic alternative. The Chief of Naval Operations, in his direction to the fleet, has branded cannibalization as "an evil maintenance practice that wasted valuable manpower" and he wants cannibalization reduced 20 percent from its present level. To understand the impact of this goal, the present level of cannibalization should be identified as well as the related costs to the Navy. Then the question of cannibalization as a cost-effective alternative to proper logistic support needs to be addressed.

C. METHODOLOGY

Throughout this thesis the reader should keep in mind that any analysis methodology chosen on any subject is largely dependent upon the situation the author is trying to portray. Policy makers, as well as thesis authors, will choose the methodology that best supports their point of view. For this reason many different methodologies will be used throughout this thesis in an effort to minimize individual prejudices.

In an effort to find out how best to measure cannibalization and why cannibalization takes place, least squares regression analysis was performed throughout this thesis. Regression analysis was performed using the general equation for a straight line namely, $Y = B + MX$, where Y is the

dependent variable and X is the independent variable. The parameter 'B' represents the Y-Intercept and 'M' is the slope of the line.

For each regression analysis performed, a coefficient of determination (r^2) was calculated, along with a t-statistic and a regression equation.

The student-t distribution was utilized to establish confidence levels for the slope coefficient where a t-statistic of greater than $\pm$ 2.228 is significant at the 95% confidence level. The effects of autocorrelation on the regression analysis were discounted for one primary reason.

There is no reason to suspect that if one month's cannibalization activity is above average that there will be a tendency for the next months cannibalization activity to be either above or below the average. Expressed another way, cannibalization during a given month should not be influenced by how much cannibalization took place the preceding month.

The following three primary sources of data were relied upon:

1. Aviation 3-M data base. The Naval Aviation Maintenance Support Office (NAMSO) keeps a complete data base on all naval aircraft. This data base contains documentation of every maintenance action on every aircraft in the U.S. Navy inventory [2,3]. Throughout this thesis, data from the 3-M data base between July 1979 and June 1980 was used.

2. Navy directives and instructions. The daily operations of aircraft squadrons are governed by instructions and directives issued by a wide range of Navy commands. These directives and instructions establish the policies and procedures which all operating aircraft squadrons must follow.

3. Interviews. Since policies and directives are subject to interpretation by those who implement them, interviews were held with squadron, functional wing, and type commander personnel.

D. ORGANIZATION

Chapter II of this thesis deals with the many different cannibalization measurement methodologies. Chapter III is concerned with why aircraft squadrons cannibalize. Chapter IV presents a comparison study between NAL and NAP. Chapter V deals with the question of cannibalization as an evil or a viable logistic alternative. The conclusions chapter is a summary.

II. CANNIBALIZATION MEASUREMENT METHODOLOGY

A. INTRODUCTION

Thus far, what cannibalization is and who the major cannibalization policy makers are has been presented. In this chapter, the different methodologies for measuring cannibalization and which methodologies have been used historically as a yardstick for cannibalization activity will be explored. As was mentioned earlier, it is important to understand that any measurement methodology chosen on any subject matter is largely dependent upon what type of environment the analyst or policy maker is trying to portray. For this reason, measurement methodologies will be divided into two major groups. In the first group explored, only those methodologies directed by the Chief of Naval Operations and, as a consequence, by the major type commanders will be presented. The second group of methodologies presented will be alternatives to the first group.

B. MEASUREMENT METHODOLOGIES DIRECTED BY HIGHER AUTHORITY

The Chief of Naval Operations [1] and both major type commanders have directed all squadron commanding officers to measure cannibalization activity in terms of cannibalization removals per 100 flight hours and cannibalization removals to total maintenance removals.

1. Cannibalization Removals Per 100 Flight Hours

Taking the number of cannibalization removals in an aircraft squadron per month and dividing it by the number of flight hours and then multiplying by 100 gives a ratio of cannibalization removals per 100 flight hours. Figures 1 and 2 display navywide F-14A and S-3A cannibalization activity in this manner.

Intuitively, this measure seems to be as good as any, but leaves the maintenance manager with a very important question to answer in using this measure: Is there a relationship or correlation between flight hours and cannibalization?

If there is a relationship or correlation between cannibalization removals and flight hours, a simple least sqaures regression analysis should provide a large coefficient of determination. Further, if a large coefficient of determination is provided in combination with a t-statistic that falls significantly outside the 95% confidence interval for testing the null hypothesis that the slope of the regression line (M) is equal to zero, then a significant relationship or correlation can be assumed. If this is the case, a regression line based on cannibalization removals per flight hour would be an extremely valuable tool in predicting cannibalization removals for different flight hour scenarios. However, great care must be taken when determining any cause and effect relationship using regression analysis to insure the two variables are causally related in the manner assumed by the form of the equation.

FIGURE 1

Cannibalization Removals Per 100 Flight Hours

F-14 Navy

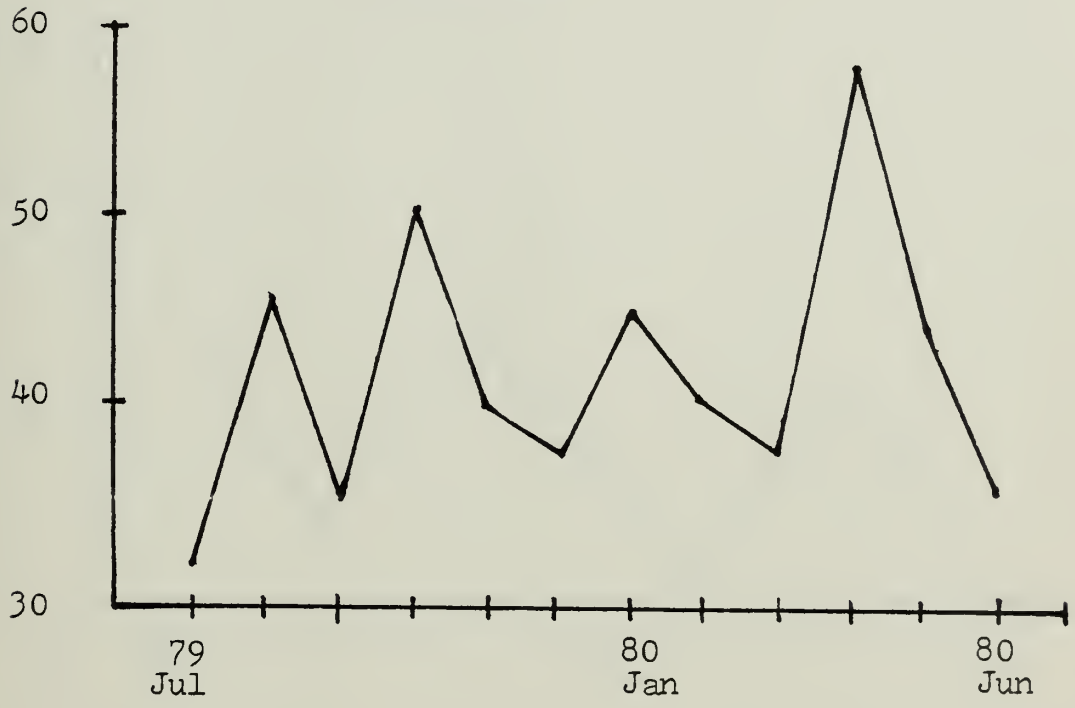
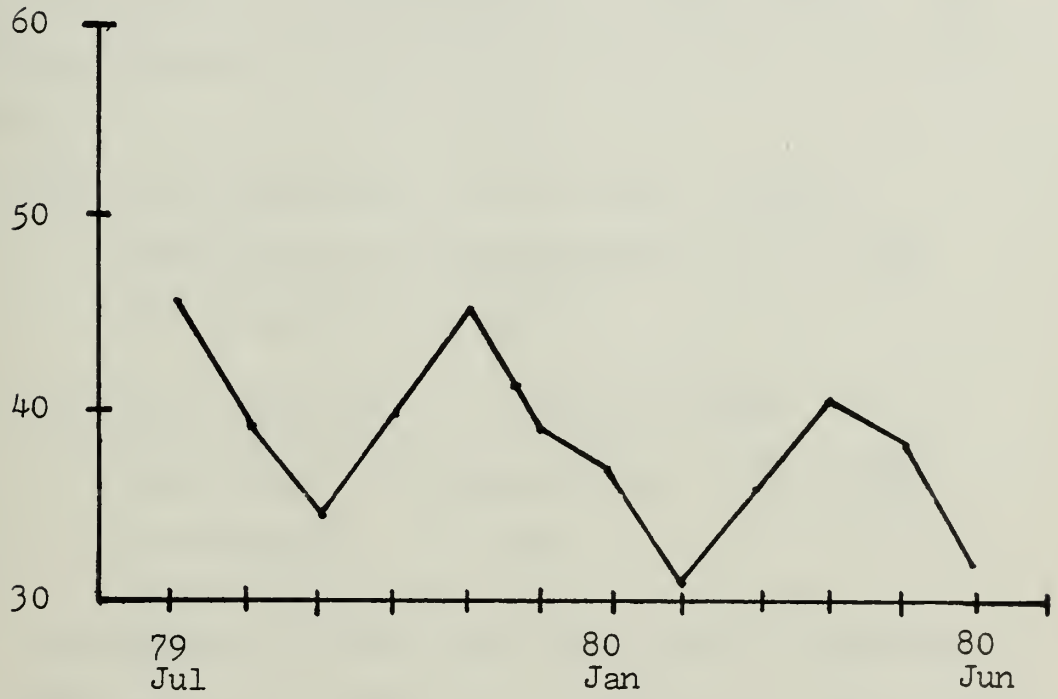


FIGURE 2

Cannibalization Removals Per 100 Flight Hours

S-3A Navy



In the case of cannibalization removals per flight hour, a fairly strong relationship should exist. After all, if aircraft are not flown then spare parts will not be needed and, if spare parts are not needed, then no cannibalization of needed spare parts would take place.

By using the general equation for a straight line, $Y = B + MX$ from Chapter I where Y corresponds to cannibalization removals and X corresponds to flight hours. The following regression results were obtained for the F-14A and S-3A:

a. F-14 equation: $Y = -273.22 + .4963X$
   Coefficient of Determination: $r^2 = .769$
   t-statistic: $t = 5.76$

b. S-3A Equation: $Y = 56.59 + .364X$
   Coefficient of Determination: $r^2 = .824$
   t-statistic: $t = 6.84$

In the case of both the F-14A and S-3A aircraft, the coefficients of determination indicate a fairly strong relationship between cannibalization removals and flight hours. This, in combination with t-statistics that are far outside of the 95% confidence acceptance region of ± 2.228, makes flight hours an extremely valuable tool for predicting cannibalization removals as operational tasking (flight hours) varies. These relationships indicate that 76.9% of the F-14A and 82.4% of the S-3A variance in cannibalization removals each month is flight hour related, and indicates

a strong relationship between cannibalization removals and flight hours. Figures 3 and 4 plot the F-14A and S-3A regression analysis data and the equations obtained.

By using a 100 flight hour base, these results say that approximately 50 cannibalization occur for every 100 flight hours of the F-14A and 36 cannibalization occur for every 100 flight hours of the S-3A.

2. Cannibalization Removals to Total Maintenance Removals

The second measurement methodology directed by the Chief of Naval Operations is cannibalization removals to total maintenance removals. By taking the number of cannibalization removals and dividing it by total maintenance removals, a ratio is obtained. Figures 5 and 6 display F-14A and S-3A cannibalization expressed as a ratio of cannibalization removals to total maintenance removals over the time frame of this data. A least squares regression analysis of cannibalization removals, Y, to total maintenance removals, X, provides not only an extremely large coefficient of determination for the F-14A and S-3A aircraft, but also provides t-statistics well outside the 95% confidence level. Figures 7 and 8 plot the F-14A and S-3A regression data. For the F-14A aircraft the regression equation for cannibalization removals to total maintenance removal was calculated to be $Y = -379.6 + .4064X$, with a coefficient of determination of .949 and a t-statistic of 13.64. The S-3A regression equation is $Y = -61.47 + .383X$, with a coefficient of determination of .937 and a t-statistic of 12.19.

FIGURE 3

Cannibalization Removals Per Flight Hour

Regression Plot - F-14A Navy

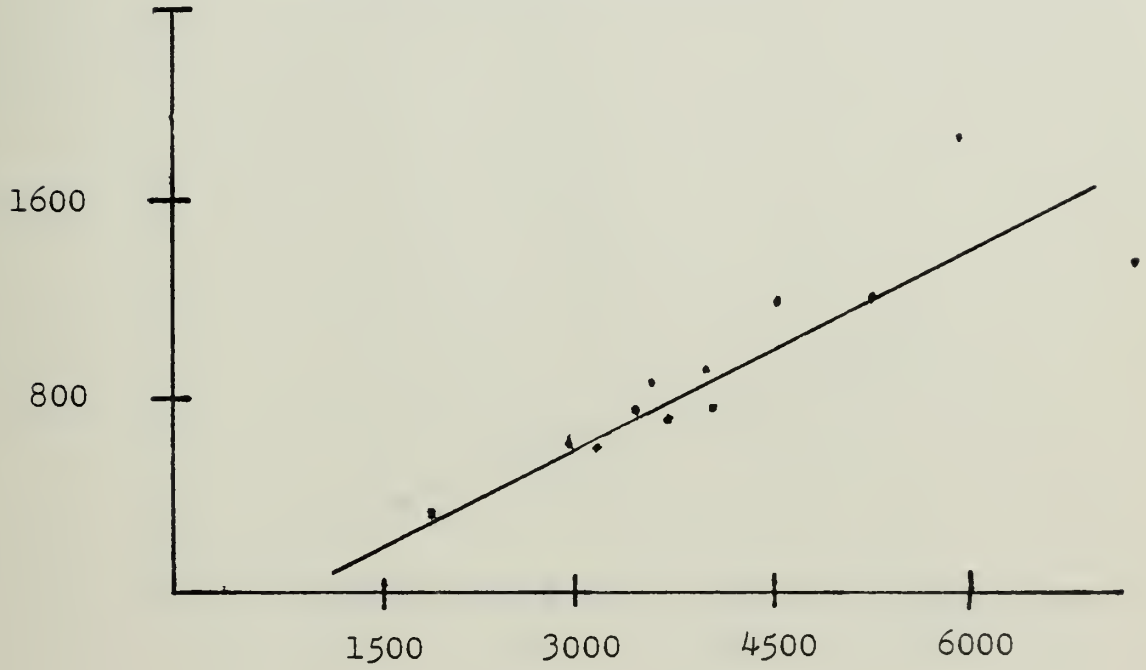


FIGURE 4

Cannibalization Removals Per Flight Hour

Regression Plot - S-3A Navy

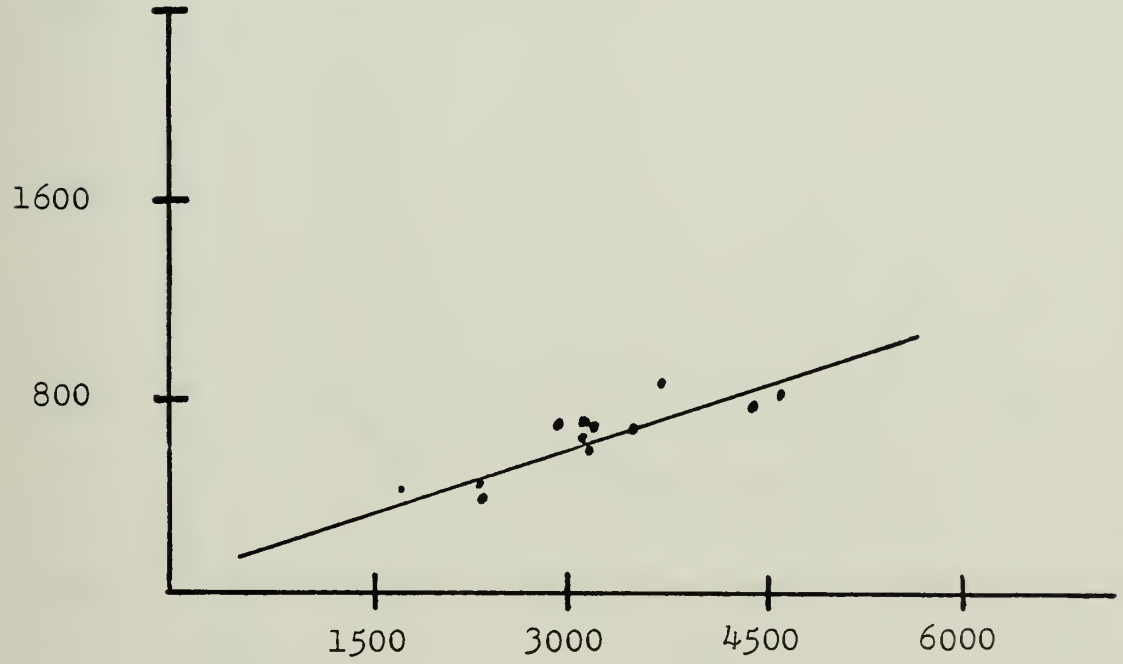


FIGURE 5

Cannibalization Removals to Total Maintenance Removals

F-14A Navy

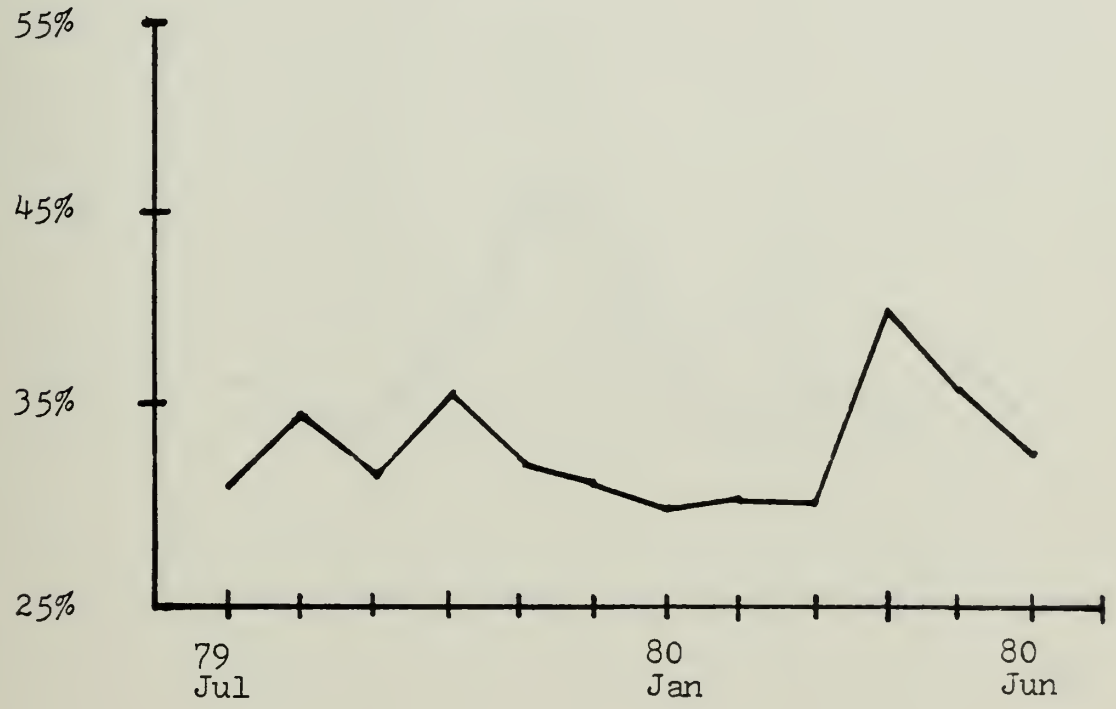


FIGURE 6

Cannibalization Removals to Total Maintenance Removals

S-3A Navy

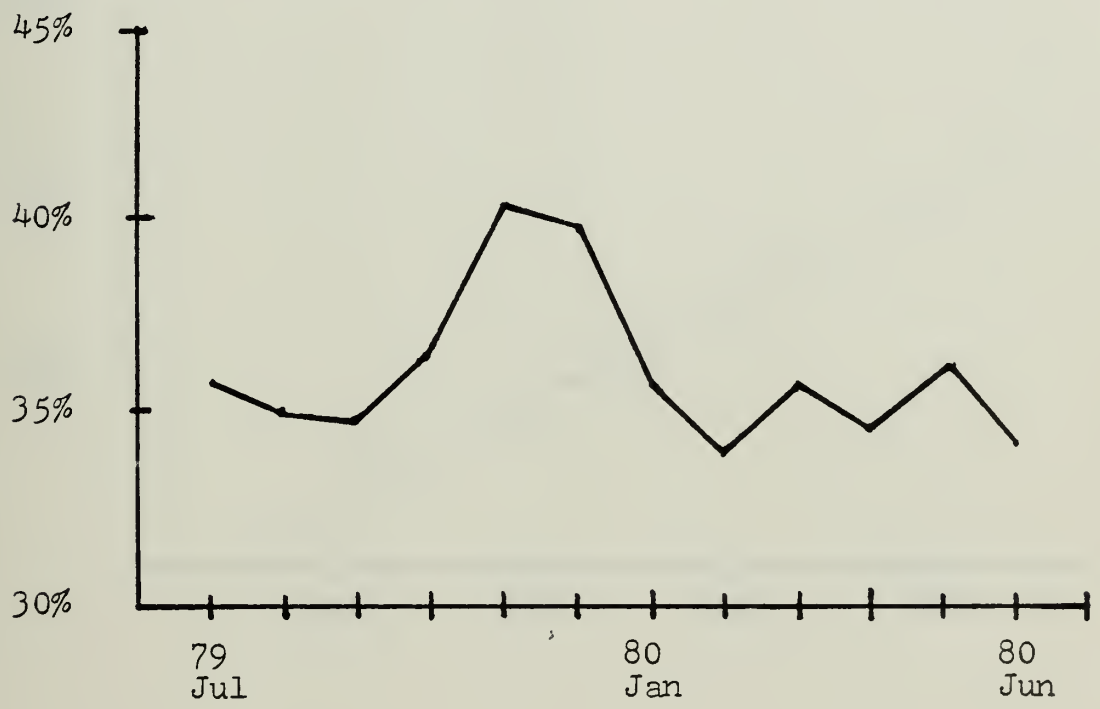


FIGURE 7

Cannibalization Removals to Total Maintenance Removals

Regression Plot - F-14A Navy

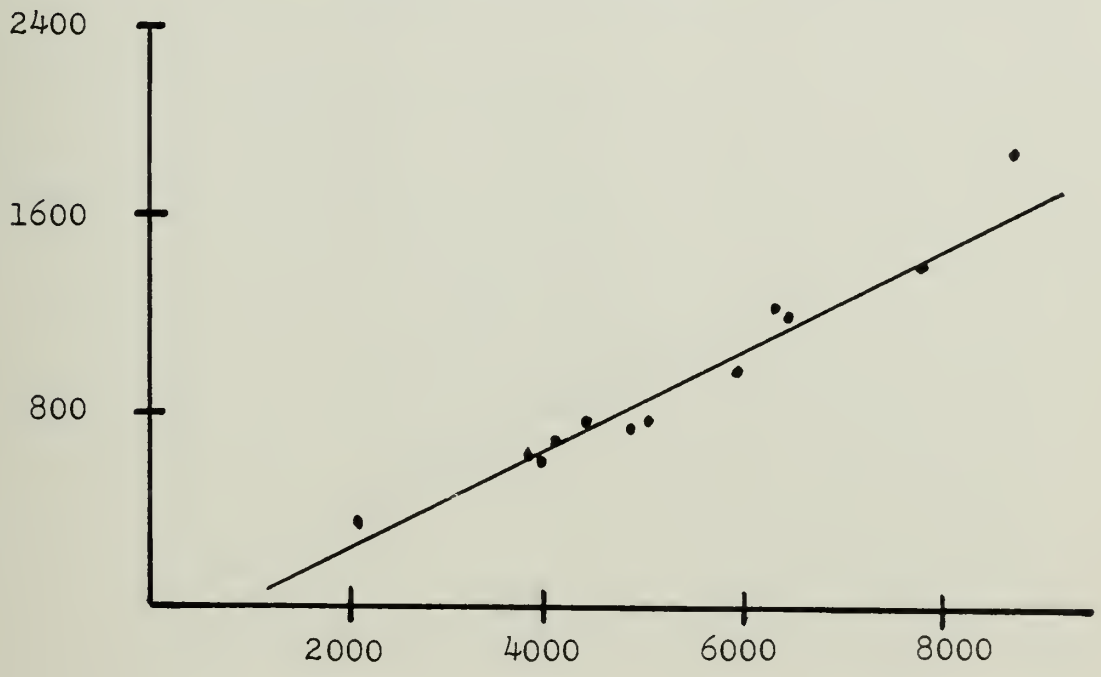
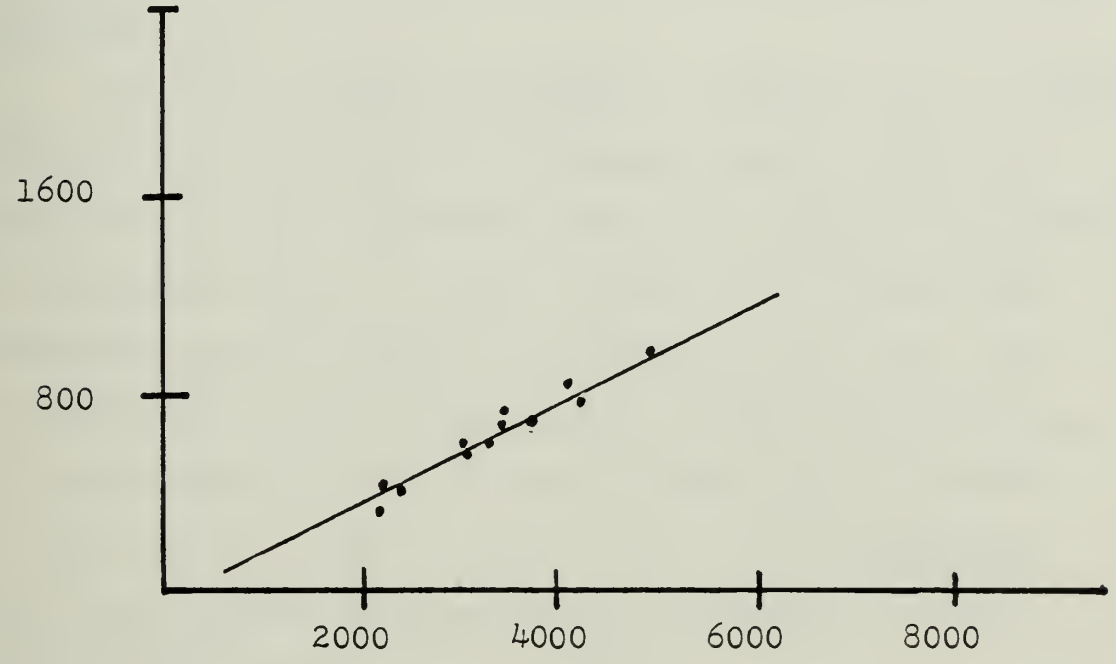


FIGURE 8

Cannibalization Removals to Total Maintenance Removals

Regression Plot - S-3A Navy



Thus we see that for the F-14A almost 41 out of 100 maintenance removals were cannibalization removals; for the S-3A it was slightly more than 38. The extremely high correlation between cannibalization removals and total removals makes this ratio an immensely valuable tool in predicting variations in cannibalization activity.

As a footnote, a regression was made to determine the correlation between total maintenance removals, Y, and flight hours, X.

The F-14A aircraft provided an equation of Y = 496.82 + .685X with a coefficient of determination of .866 and t-statistic of 8.03. Likewise, the S-3A aircraft's equation was calculated to be Y = 52.90 + .937X with a coefficient of determination of .905 and a t-statistic of 9.76. This data indicates that 68.5 maintenance removals were made per 100 flight hours of the F-14A and 93 maintenance removals were made per 100 flight hours of the S-3A. As expected, flight hours drives total maintenance removals of which cannibalization removals are a subset.

C. ALTERNATIVE METHODOLOGIES

Both methodologies directed by higher authority are very useful in the sense that cannibalization removals can be predicted with fairly high accuracy for a given flight hour figure, but more information is needed to provide a total cannibalization picture. The real impact of cannibalization on a squadron is on manpower in the total maintenance effort. Therefore, methodologies relative to manpower are introduced in this section.

1. Cannibalization Manhours to Total Maintenance Manhours

Cannibalization manhours are simply those manhours expended by a squadron cannibalizing components. Total maintenance manhours represents all manhours expended doing maintenance including those manhours spent cannibalizing.

Cannibalization manhours divided by total maintenance manhours gives the maintenance manager an indication of the impact of cannibalization in the overall maintenance effort. Figures 9 and 10 express this ratio for the F-14A and S-3A aircraft over the time span of data. The yearly mean ratio for the F-14A and S-3A aircraft was .048 and .058 respectively. This ratio on a yearly basis tells major policy makers that about five percent of the total maintenance manhours expended in a year are cannibalization-related.

By using this ratio in conjunction with the yearly cannibalization removals to total maintenance removals ratio, the maintenance manager can get a better picture of the impact of cannibalization removals to the total maintenance effort. For example, the F-14A aircraft averages 4.8 percent of all maintenance manhours cannibalizing, but 33 percent of all maintenance removals are cannibalization removals.

The maintenance manager must be very careful in using this data in combination. Total maintenance manhours are made up of a combination of removals, scheduled maintenance, unscheduled maintenance and support-related manhours.

FIGURE 9

Cannibalization Manhours to Total Maintenance Manhours

F-14A Navy

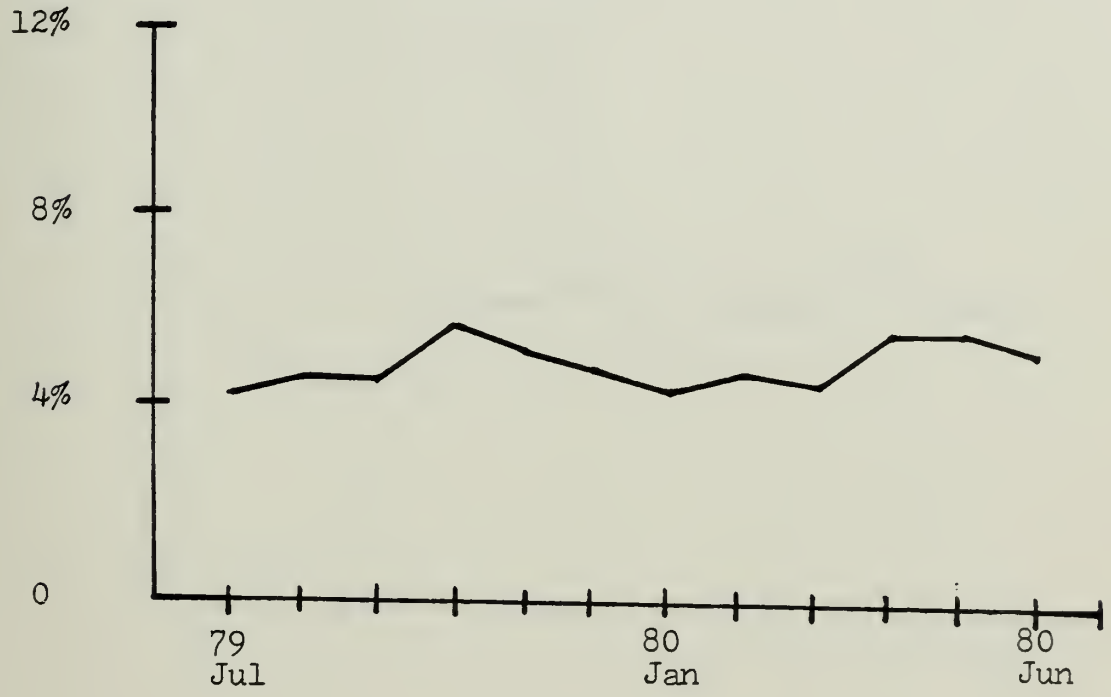
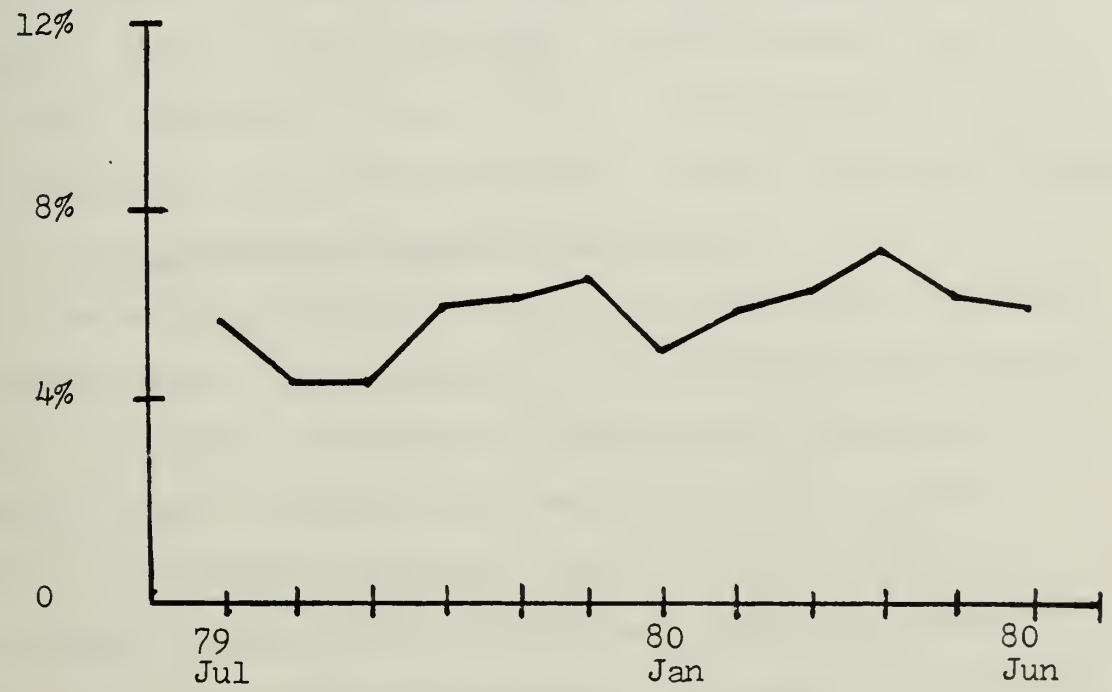


FIGURE 10

Cannibalization Manhours to Total Maintenance Manhours

S-3A Navy



A least squares regression analysis of cannibalization manhours, Y, to total maintenance manhours, X, for the F-14A aircraft navywide was calculated to be Y = -915.5 + .0538X, with a coefficient of determination of .923 and a t-statistic of 10.94. The S-3A regression equation is Y = -747.7 + .0675X, with a coefficient of determination of .880 and a t-statistic of 8.56. Figures 11 and 12 display the F-14A and S-3A regression plot data. A better measure would be cannibalization manhours to total removal manhours. Unfortunately, this data is not available in the aviation 3-M data base. If it were available, a much more realistic picture would be obtained.

2. Cannibalization Removals Per Sortie

Measuring cannibalization actions in terms of flight hours only masks a more important cause of equipment failures, namely, the number of sorties. Ten one-hour flights produce the same number of flight hours as one ten-hour flight. However, an aircraft flying ten one-hour flights has ten times as many shocks from take-offs and landings, as well as ten times more starts and stops on the engine and avionics components.

By taking cannibalization removals and dividing it by the number of sorties, a more significant ratio than just flight hours is obtained. Figures 13 and 14 display this methodology for the F-14A and S-3A aircraft.

A least squares regression analysis of the F-14A aircraft using the number of cannibalization removals,

FIGURE 11

Cannibalization Manhours to Total Maintenance Manhours

Regression Plot - F-14A Navy

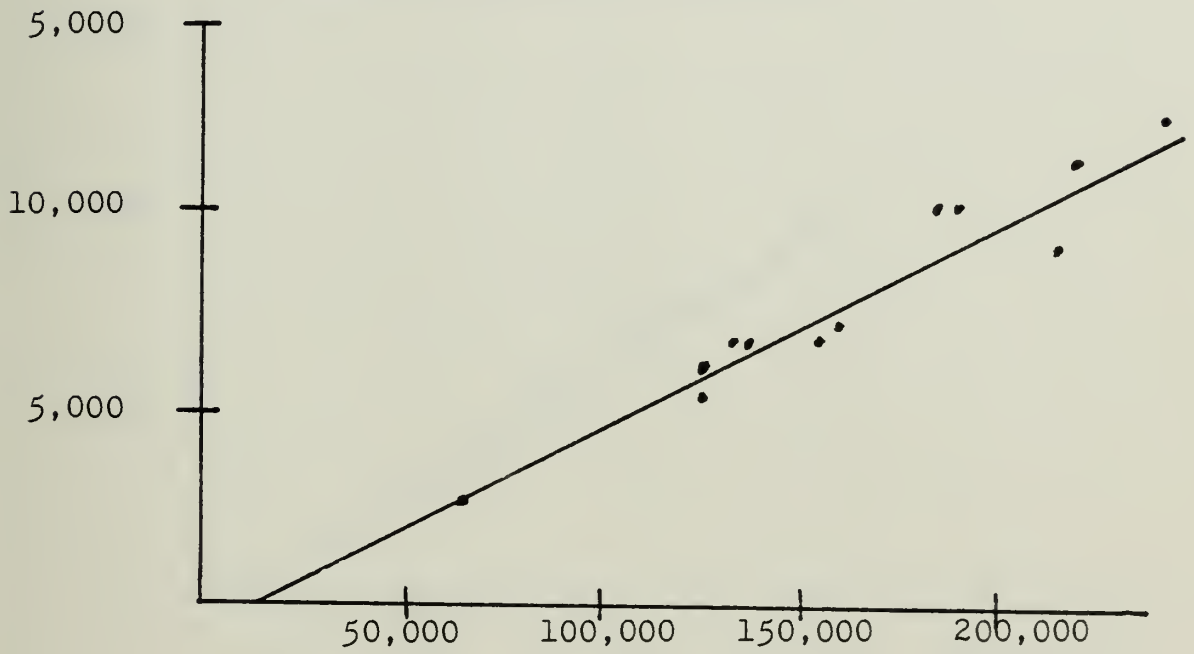


FIGURE 12

Cannibalization Manhours to Total Maintenance Manhours

Regression Plot - S-3A Navy

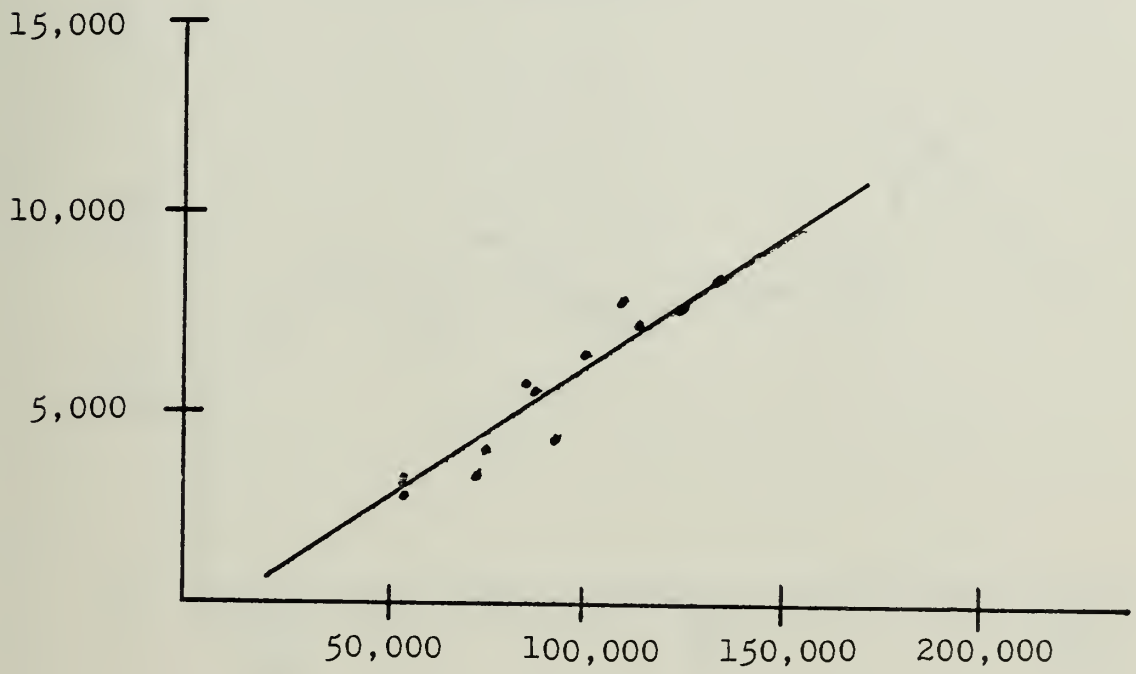


FIGURE 13

Cannibalization Removals Per Sortie

F-14A Navy

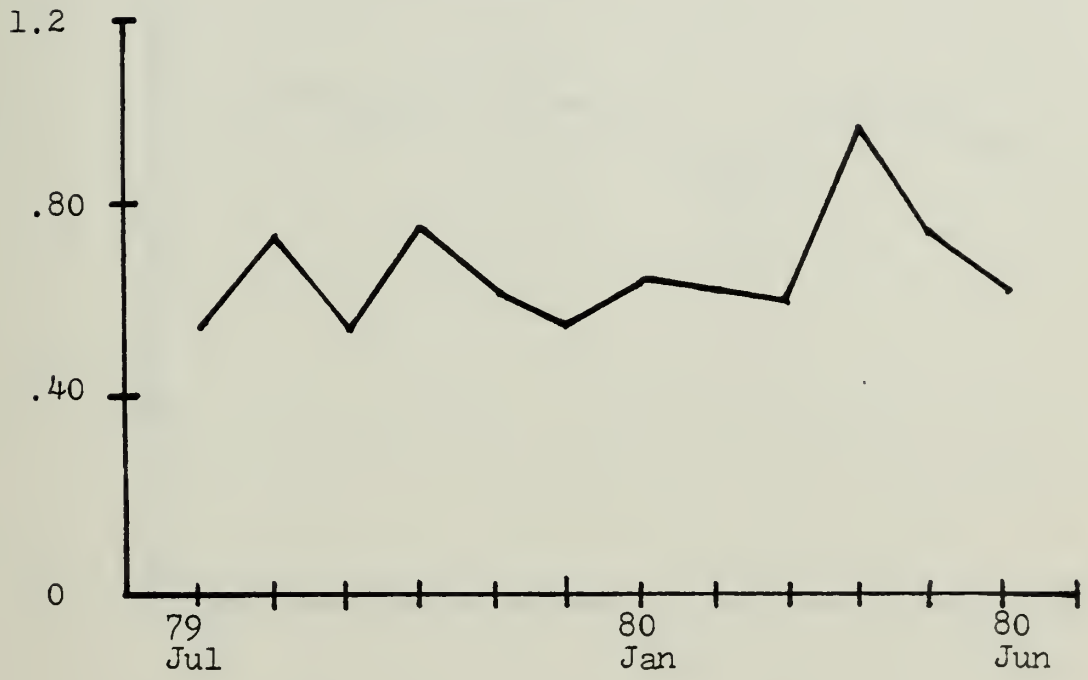
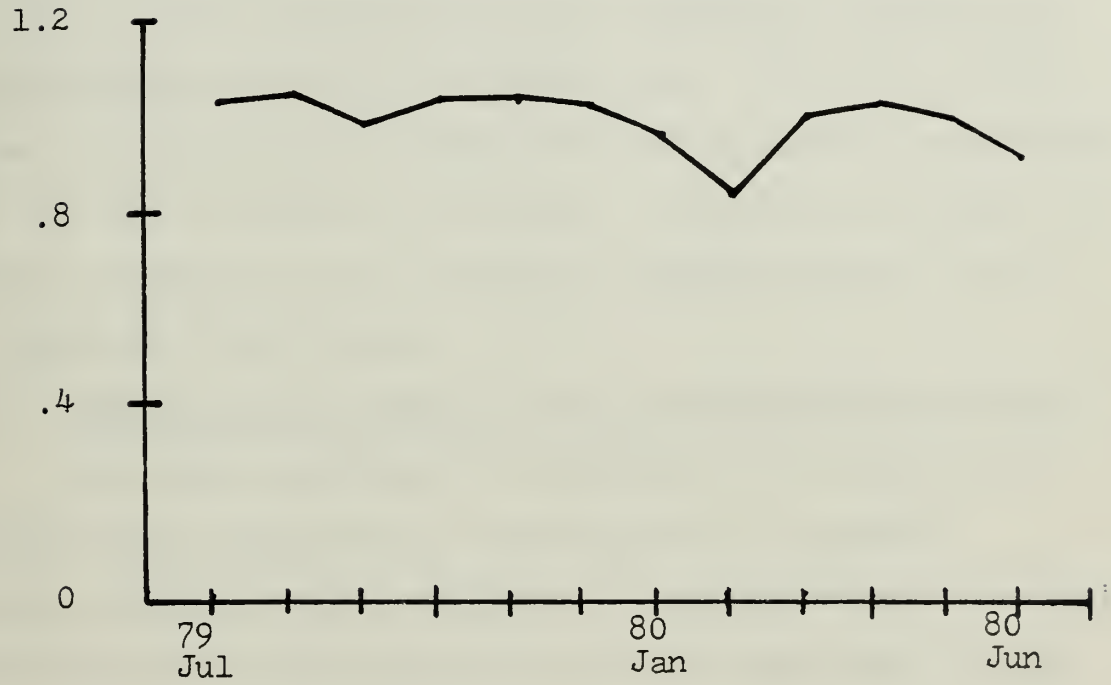


FIGURE 14

Cannibalization Removals Per Sortie

S-3A Navy



as Y and the number of sorties as X produces a regression equation of Y = -528.97 + .8859X with a coefficient of determination of .825 and a t-statistic of 6.87. The S-3A aircraft provides a regression equation of Y = -76.88 + 1.08X with a .903 coefficient of determination and a t-statistic of 9.64. Figures 15 and 16 display the F-14A and S-3A regression data plot and regression lines.

Both coefficients of determination are larger than the .769 and .824 obtained from the regression analysis of cannibalization removals per flight hour. From this information, the maintenance manager and policy makers can conclude that, for the F-14 and S-3 aircraft the number of sorties is a better explainer of the number of cannibalization than is the number of flight hours.

3. Cannibalization Manhours Per Cannibalization Removal

The next measurement methodology to be explored is cannibalization manhours per cannibalization removal. Dividing cannibalization manhours by cannibalization removals gives the maintenance manager and policy maker some insight into how much manpower is needed for the average cannibalization removal. Figures 17 and 18 illustrate its value for the F-14A and S-3A aircraft.

This methodology should give the maintenance manager a feel for what is being cannibalized rather than how much cannibalization is taking place. A high manhour per cannibalization removal average could mean that the components being cannibalized are harder to remove and replace than a lower

FIGURE 15

Cannibalization Removals Per Sortie

Regression Plot - F-14A Navy

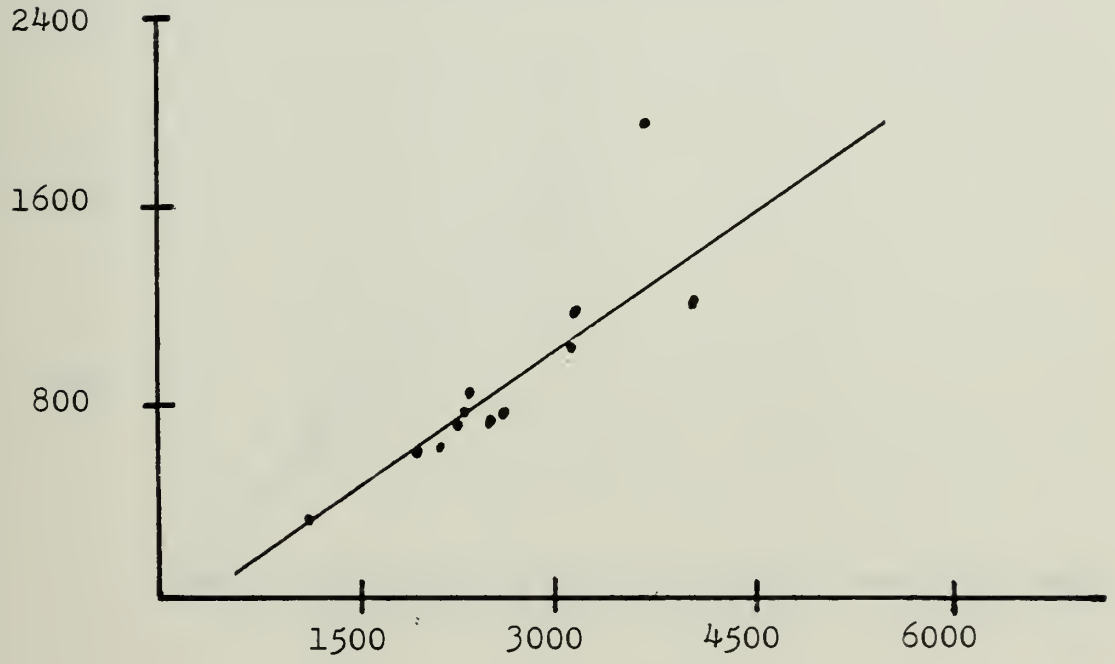


FIGURE 16

Cannibalization Removals Per Sortie

Regression Plot - S-3A Navy

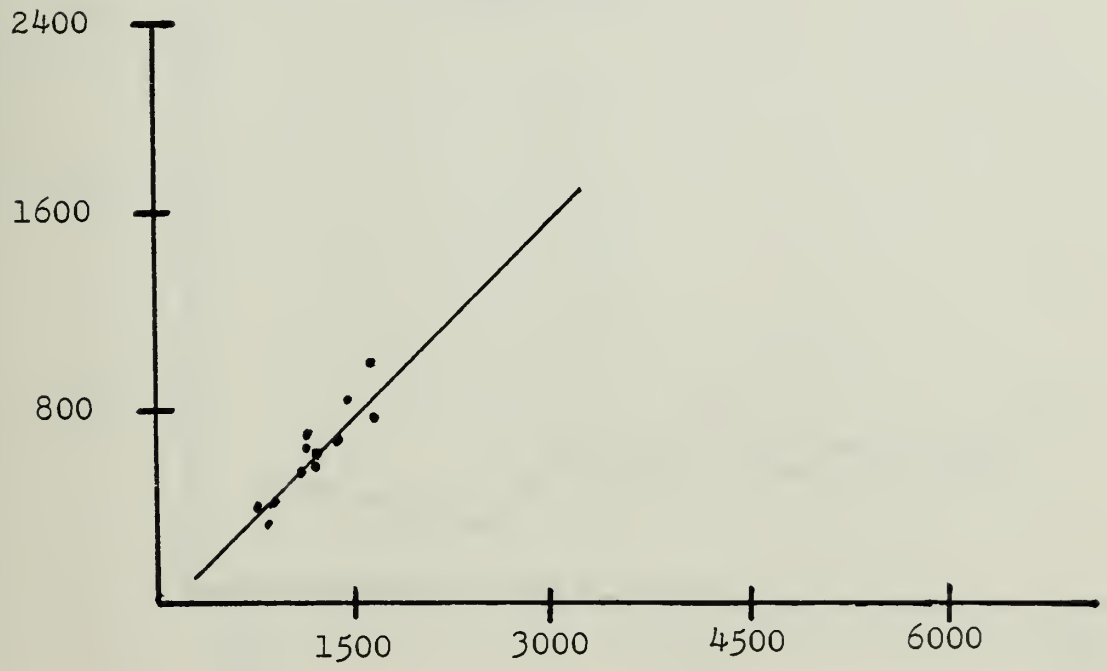


FIGURE 17

Cannibalization Manhours Per Cannibalization Removal

F-14A Navy

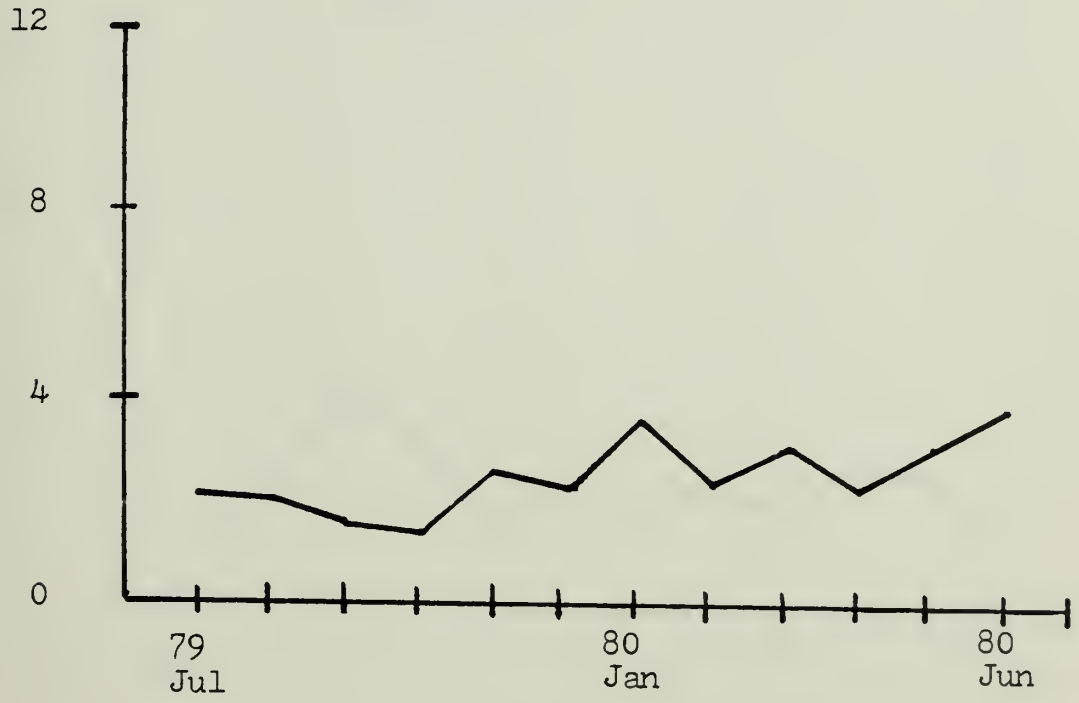
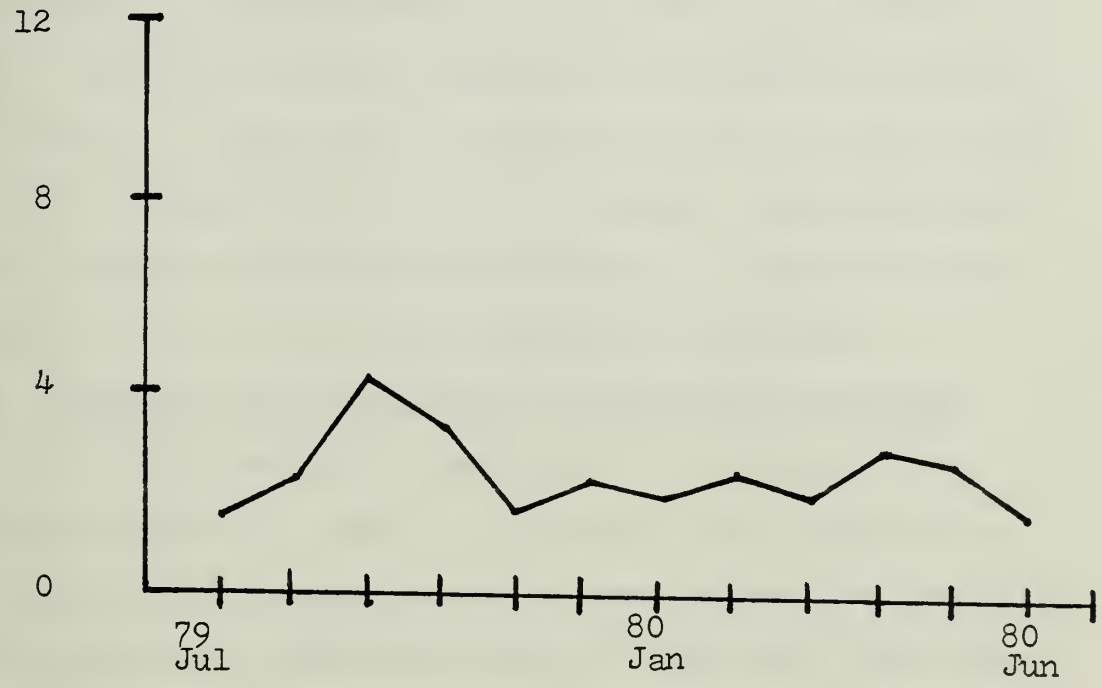


FIGURE 18

Cannibalization Manhours Per Cannibalization Removal

S-3A Navy



average. This average can be used by policy makers in searching through the 3-M data base to see if there is one particular system which is responsible for a sudden rise or fall in the average.

A regression analysis of cannibalization manhours, Y, to cannibalization removals, X, for the F-14A aircraft provided a regression equation of Y = 2025.4 + 3.30X, with a coefficient of determination of .841 and a t-statistic of 7.29. The S-3A aircraft produced a regression equation of Y = -647.5 + 5.08X with a t-statistic of 5.29 and a coefficient of determination of .737. Clearly, cannibalization removals create cannibalization manhours. Figures 19 and 20 display the F-14A and S-3A regression data plot.

4. Cannibalization In Terms Of Equivalent Manpower

The total manhours available to a squadron are relatively constant; what is done with those manhours is not. What the policy maker needs to know is how many manyears can be saved by not cannibalizing and what does that represent in terms of cost. By knowing this, the policy maker can decide where best to commit resources to minimize the impact of cannibalization and if more resources will be expended than saved in reducing cannibalization.

Aircraft squadron manning is based on aircraft configuration, computed workload, specified operating profiles and required operational capabilities. Manhours are based on 63 productive manhour per week per man in accordance with

FIGURE 19

Cannibalization Manhours to Cannibalization Removals

Regression Plot - F-14A Navy

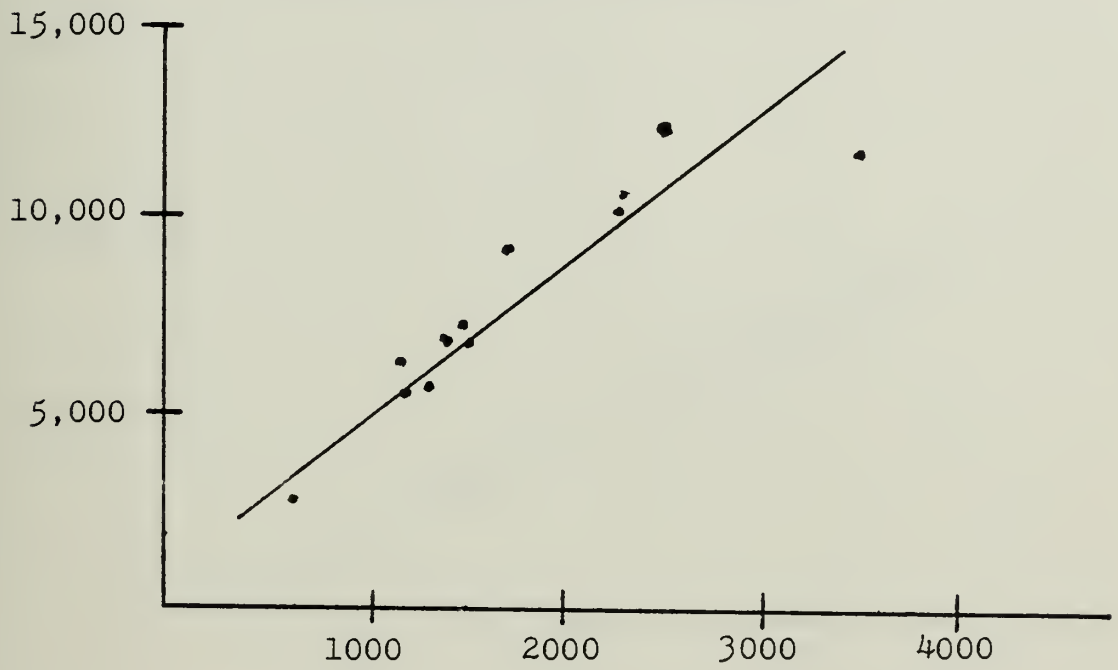
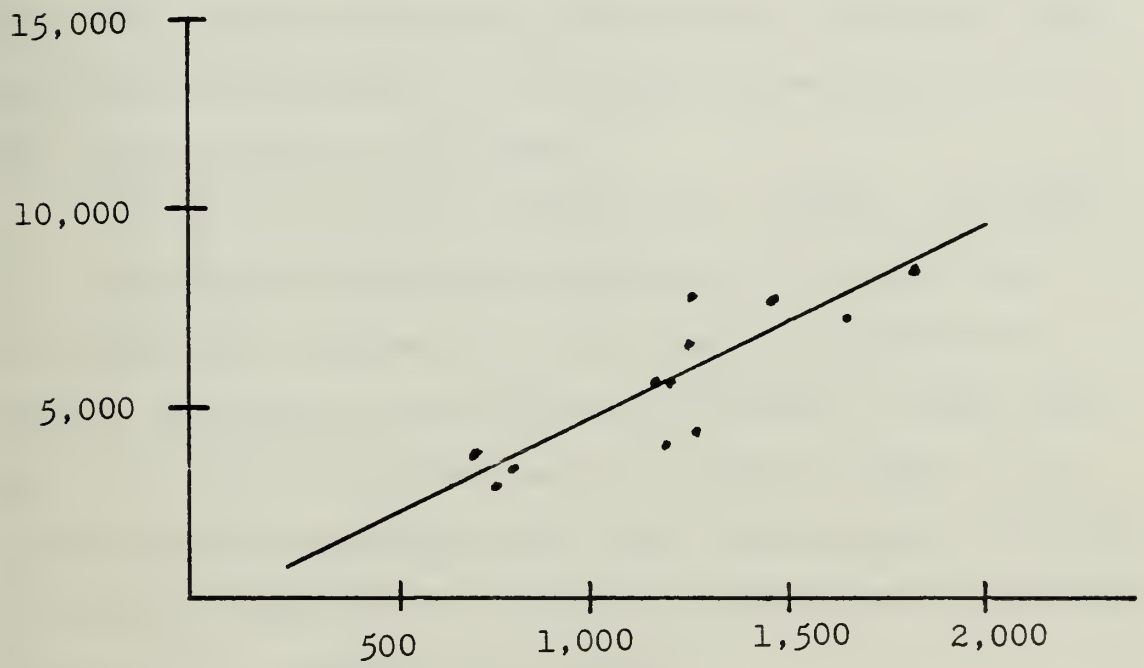


FIGURE 20

Cannibalization Manhours to Cannibalization Removals

Regression Plot - S-3A Navy



Chief of Naval Operations Instruction 5320.170A. This means each maintenance technician is expected to perform 252 hours of maintenance each month. By dividing cannibalization manhours by 252, equivalent man-months spent cannibalizing is obtained. Figures 21 and 22 illustrate this methodology for the F-14A and S-3A aircraft navywide.

With this information, a policy maker now has a figure that can easily be converted into dollars. By taking the average salary of a maintenance technician for a year and multiplying it by the manyears expended, a total dollar figure is obtained.

The F-14 aircraft squadrons, for example, expended 379.5 man-months navywide cannibalizing in a single year. By dividing this figure by 12, the number of months in a manyear, we obtain 31.62 equivalent manyears. Thus, navywide, if F-14A cannibalization was reduced to zero, 31.62 manyears would be available for other maintenance. Dividing 31.62 by the number of F-14 squadrons, which is 16, provides a value of 1.97 manyears per squadron.

If these 1.97 cannibalization manyears plus all other maintenance manyears are less than the total available manyears per squadron then no dollar savings can occur by a reduction in cannibalization. If, however, this sum is greater than available manyears to a squadron, some amount of savings can occur by a reduction in cannibalization. It is not at all apparent that the most cost-effective way to do this is by reducing cannibalization. Other areas of maintenance should also be examined.

FIGURE 21

Equivalent Manmonths Cannibalizing

F-14A Navy

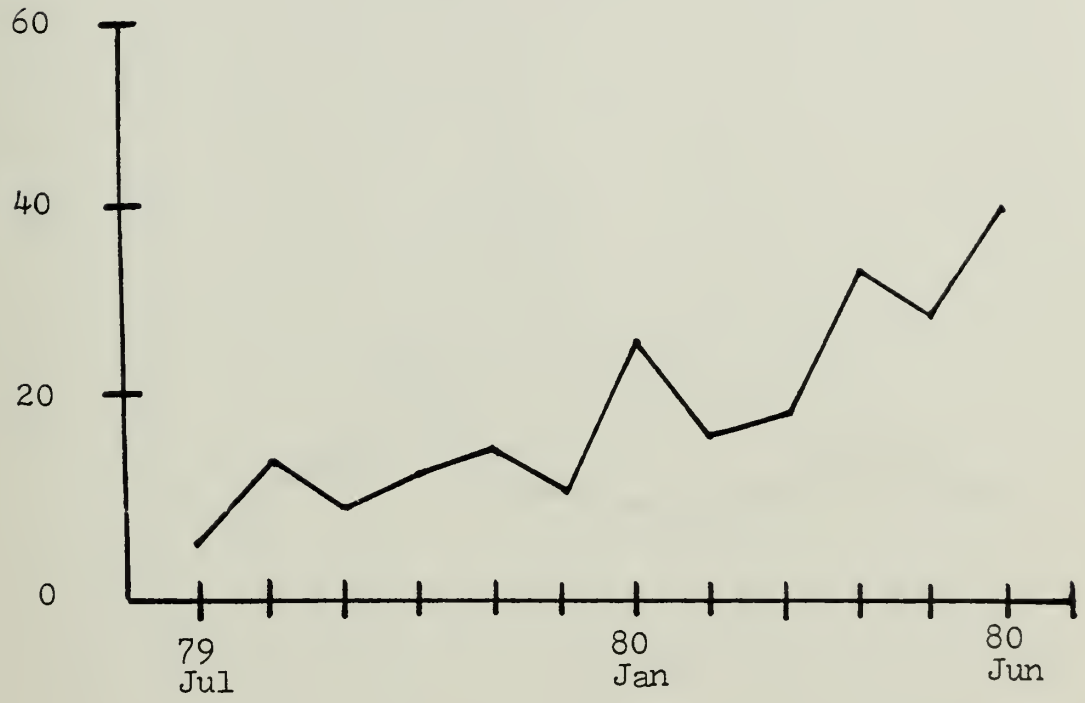
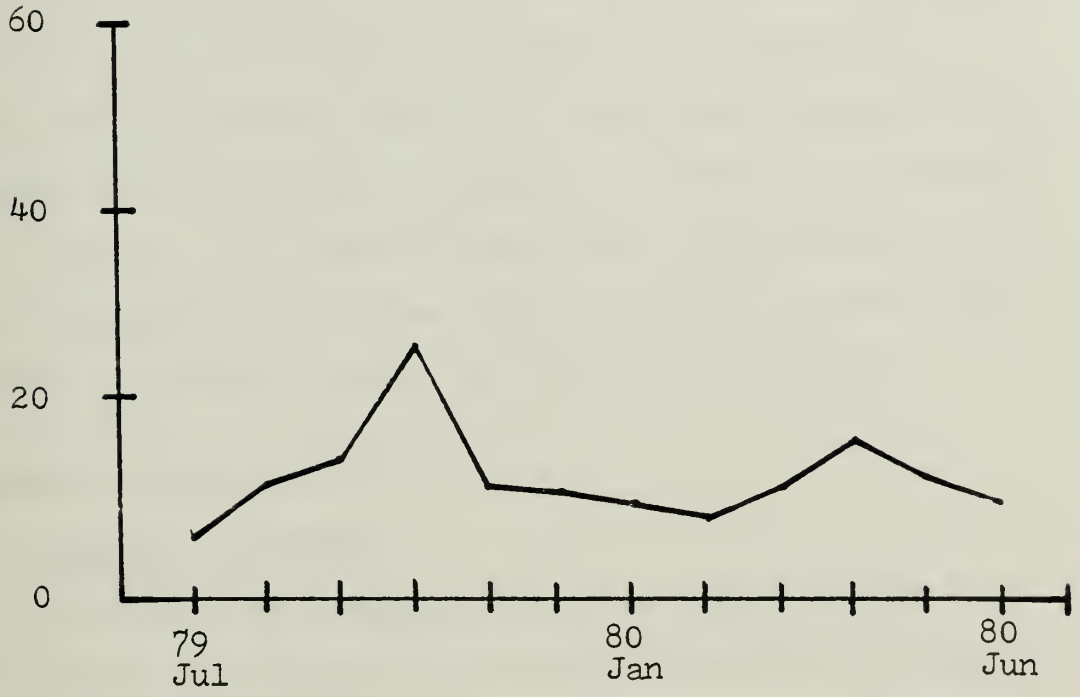


FIGURE 22

Equivalent Manmonths Cannibalizing

S-3A Navy



III. WHY DO SQUADRONS CANNIBALIZE?

A. INTRODUCTION

In this chapter, the reason why aircraft squadrons cannibalize will be examined. However, it is important to remember that there are as many different reasons to cannibalize as there are aircraft squadrons and maintenance managers. Each squadron works in a different management environment with different constraints as well as different goals to fulfill. By understanding what cannibalization is and why cannibalization takes place, we will be better able to measure its overall impact on aviation squadrons.

B. SQUADRON CANNIBALIZATION

1. Material Shortages

The first and probably the most obvious reason for squadron-level cannibalization is that a material shortage exists and the local supply system simply does not have a replacement asset. In this case, the squadron level maintenance manager has no choice but cannibalization if the aircraft is to be restored to a mission capable status.

In the case of a material shortage of a replacement asset that cannot be cannibalized (i.e., an o-ring seal for a hydraulic cylinder), the maintenance manager's only alternative is to wait for a replacement asset. However, that aircraft then becomes available as a source for cannibalization of other assets.

Under the Naval Aviation Maintenance Program, supply shortages are measured by a not mission capable supply (NMCS) rate expressed in terms of its percent impact on aircraft readiness [4]. Aircraft readiness is obtained by adding all the hours in a month that an aircraft is ready for flight (mission capable) and dividing those hours by 720 hours, the number of hours in a 30 day month. For example, if an aircraft was mission capable for 555 hours in a month, its readiness would be 555 divided by 720 or 77 percent readiness.

Not mission capable supply is computed by summing all the hours in a month an aircraft is not ready for flight (not mission capable) due to material shortages and dividing that value by 720 hours per 30 day month. For example, if the sum of NMCS hours is 150 then the NMCS rate would be 150 divided by 720 or 20.8 percent NMCS.

If NMCS drives cannibalization then squadron level cannibalization would be expected to vary as a function of the NMCS rate. By performing a regression analysis of the number of cannibalization removals, Y, as a function of the NMCS rate, X, for the F-14A aircraft, the equation was calculated to be $Y = 594.5 + 53.18X$ with a coefficient of determination of .048 and a t-statistic of .710. The S-3A aircrafts equation was found to be $Y = 1769.2 + -.17.33\ X$ with a coefficient of determination of .049 and a t-statistic of .717. In both cases the t-statistic is well within the 95% confidence level of ± 2.228. This indicates that the

null hypothesis that the slope of the regression line is equal to zero is not rejected. The very small coefficients of determination confirms the conclusion that the NMCS rate has little or no relationship to cannibalization removals. Figures 23 and 24 display F-14A and S-3A cannibalization removals to NMCS regression data plots.

Material shortages will drive an individual decision to cannibalize, but do not support overall cannibalization rates. Squadron level maintenance managers consolidate unfilled supply requirements to as few aircraft as possible in order to maximize readiness. One would assume this shift to be true since no one would cannibalize a part if a replacement asset was available. Without this part consolidation, we might expect to see the NMCS rate become more proportional to cannibalization activity.

This leads to the second reason for cannibalization, that of having a supply asset, but not being able to issue the asset to the squadron in the required time frame.

2. Supply Response Time

The aircraft carrier environment of today requires aircraft maintenance managers to launch aircraft in a 20-30 minute time-window. From the time aircraft-recovery is over until the time of the next launch of that aircraft is, at most, 30 minutes. Because of this, a replacement component that takes more than 30 minutes to deliver is of little use to a maintenance manager.

FIGURE 23

Cannibalization Removals to NMCS
Regression Plot - F-14A Navy

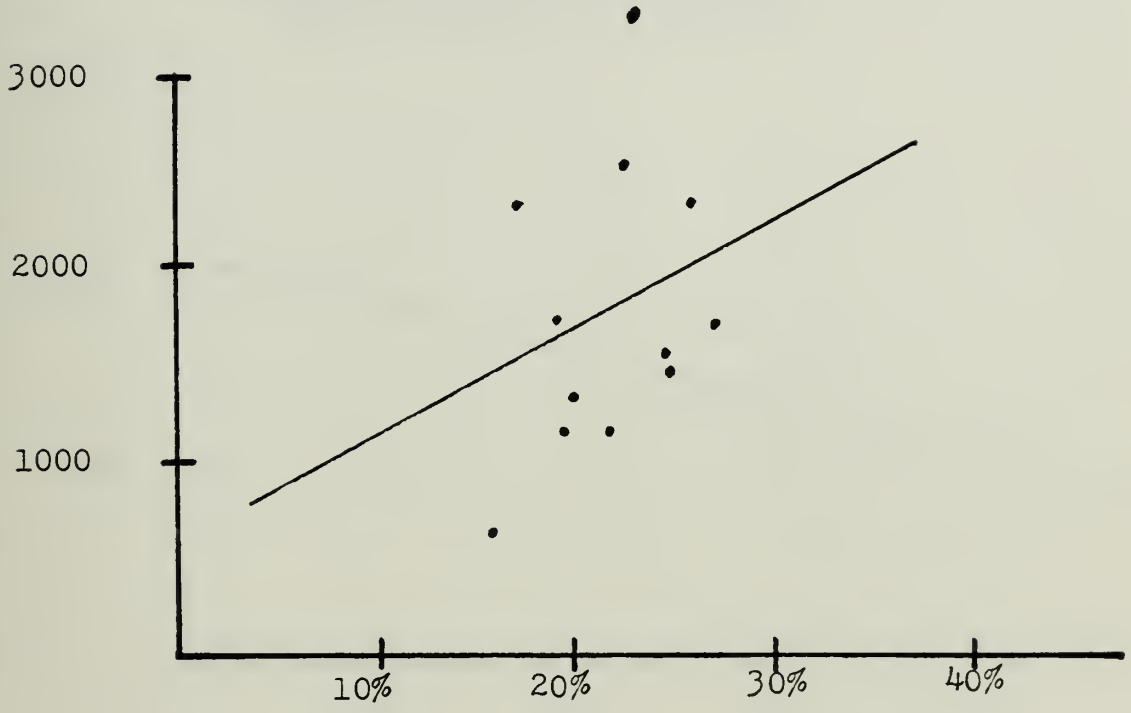
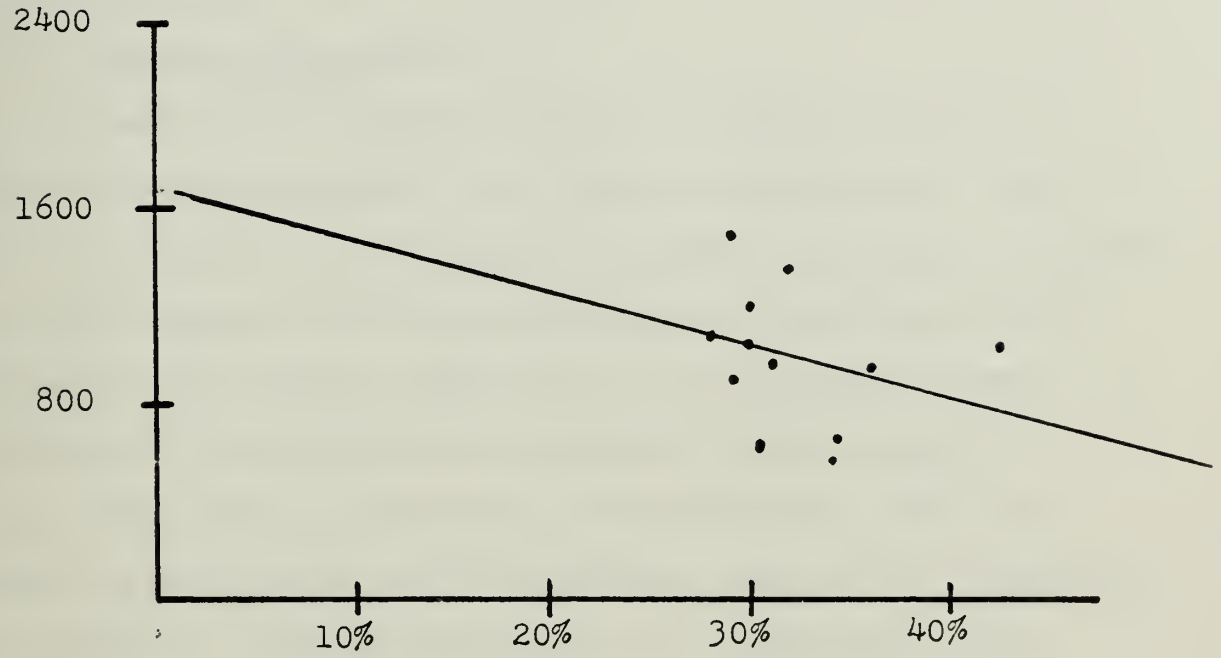


FIGURE 24

Cannibalization Removals to NMCS

Regression Plot - S-3A Navy



Even though a local supply activity could be 100 percent effective in meeting the Chief of Naval Operations goal of one hour supply response time, it may not even come close to meeting the supported squadrons material needs.

Many a maintenance manager has directed the cannibalization of a component prior to even ordering a replacement component simply because the component was needed now and not one hour from now.

3. Readiness Reaching

Readiness is measured against a twenty-four hour day and a thirty day month, or a total of 720 hours. Each time the aircraft is not ready for flight (not mission capable), the time it spends in a not ready status is subtracted from 720 hours to get actual ready time. The readiness measure is a percentage figure which is obtained by summing all the actual ready time and dividing it by 720 hours. The Chief of Naval Operations has set a readiness goal for all squadrons of 70 percent. Aircraft readiness is so important to the Navy that it has become a determining factor in the career success or failure of squadron commanding officers. Aircraft can be not ready for flight for many reasons, most of which are internal to the squadron, but it is much easier to blame a supporting supply activity for lack of readiness than to admit to the world that internal problems are the primary reasons for not being ready.

To achieve the 70 percent readiness goal, an aircraft must be mission capable for 504 hours each month. Now with this goal in mind, readiness reaching as it applies to cannibalization and achieving 70 percent readiness can be explained.

The typical squadron maintenance crew while shore-based works in two eight-hour shifts, five days a week (1/3 to 1/2 of all F-14A and S-3A squadrons operations are shore-based at any given time). This means, little or no maintenance is performed on weekends. Assuming a four weekend month, that means 192 hours of readiness time is accumulated over the four weekends. In other words, 38 percent of the 504 hours required to meet Chief of Naval Operation standards occurs during a time period in which no maintenance is performed. Add to that the eight hours a day that are not covered by a two-shift work force and the percentage is increased to 73 percent of the 504 hours necessary to reach CNO standards.

These figures make it very profitable in terms of readiness to cannibalize on Fridays and during the second shift during the week even if the aircraft is not needed for the next day's flight schedule. By cannibalizing from other aircraft and consolidating material shortages, supply response times and backorders are discounted. All that needs to be done is order a part, then cannibalize. Why wait on a system response or risk a not-in-stock situation when the required readiness can be achieved through

cannibalization. By picking and choosing cannibalization time frames, readiness can be maximized at the expense of a few extra manhours.

This readiness reaching policy consolidates NMCS requirements to the minimum number of aircraft, avoids supply response delays, and maximizes readiness that can be essential to the squadron commanding officer.

4. Operational Commitments

Many type commanders view operational commitments as the only valid reason for cannibalization. After all, if the aircraft is not needed to meet the flight schedule why should we ask our maintenance technicians to expend double maintenance manhours just to achieve readiness. This view says, "Cannibalize when operational commitments require it and allow the supply system to react all other times." The CNO also directs that operational commitments are the only valid reason for cannibalization in his instructions to squadron commanding officers. Unfortunately, the CNO still requires 70 percent readiness to be achieved.

Squadron commanding officers have so many number one priorities that the best they can ever hope to do is satisfice. Their rationale tends to be that if readiness is 70 percent and all operational commitments are made and squadron personnel are relatively happy, then no one would ever argue with the amount of cannibalization activity. This view is also supported by a promotion system that emphasizes readiness rather than cannibalization activity.

Operational commitments are measured in terms of flight hours. This has led to measuring cannibalization actions per flight hour. This measuring criteria was discussed in detail in Chapter II.

5. Avoid The Risk Of A Stock Out Or Missed Sortie

The supply system goal as set out in the Naval Aviation Maintenance Program is to deliver 90 percent of all squadron issue-group-one demand in one hour. Issue-group-one material is that material that makes an aircraft not mission capable or reduced mission capable. This means that, if a supporting supply activity is reaching the established goal, ten percent of the time some period of greater than one hour, and in some cases weeks, will be required to deliver issue-group-one material.

In the case of the F-14A and S-3A, this 90 percent goal has never been achieved navywide. The F-14A and S-3A have averaged 80 percent and 73 percent, respectively, for the last 12 months.

The maintenance manager's dilemma now becomes that of risking ordering a part and waiting for it to be delivered, while knowing that at least 20 percent of the time, and in the case of the S-3, 27 percent of the time, the order will not be filled, or cannibalize a sure thing and not miss a scheduled flight. Many maintenance manager view cannibalization as risk avoidance in its purest form.

6. Troubleshooting a Complex Aircraft

Very few, if any, maintenance managers would argue against the statement that naval aircraft have become more and more complex with each generation. Training demands on new maintenance technicians are far in excess of the demands placed on past personnel.

To minimize the adverse impact on maintenance and troubleshooting skills, modern aircraft such as the F-14A and S-3A rely heavily on built-in-test (BIT) features for troubleshooting. BIT simply tells the maintenance man or woman what is wrong with the system and which component or components has failed. This system works well, most of the time, until the BIT feature fails or a failure occurs that is outside the monitoring capacity of BIT. In the latter case many error-free components may be changed before a fault is corrected.

The removal of error-free components by a squadron level maintenance department is monitored by the supporting intermediate maintenance activity. This monitoring takes place so that intermediate maintenance managers can alert squadron-level maintenance managers of BIT problems or faulty training of maintenance troubleshooters.

Squadron-level maintenance managers and technicians now become caught between a BIT system or troubleshooter training system that has failed and an intermediate maintenance activity that monitors error-free component removal.

To avoid this dilemma, the maintenance technician uses a known good system from another aircraft to troubleshoot the bad system. Simply put, the maintenance manager directs the cannibalization of a good aircraft to fault isolate a bad aircraft.

This type of cannibalization hides poor troubleshooting performances from the intermediate maintenance activity and perpetuates marginal BIT system features. By cannibalizing a good aircraft, to fault isolate a bad aircraft, squadron level maintenance managers minimize their error-free removal percentages at the cost of a few extra manhours. If squadron level maintenance managers viewed error-free reporting by the intermediate maintenance activity as an indicator of a possible training or BIT system problems rather than an indicator of their management ability, then cannibalization for troubleshooting would be minimized.

7. Maintainability

In recent years the aircraft acquisition process has learned from past mistakes and has made maintainability a major design criterion for the acquisition of naval aircraft. Maintainability is the ability to repair an aircraft in a given time period assuming trained personnel and proper replacement parts.

The F-14A and S-3A have relied heavily on maintainability engineering from the very beginning of the acquisition process. However, both aircraft have the highest cannibalization

rates by any methodology ever experienced by naval aircraft. This cannibalization can, inpart be attributed to having an aircraft whose component parts can be removed and replaced so quickly (in most cases in less than 15 minutes elapsed time) that waiting for a supply system to react to demand does not seem to be an alternative worth considering.

IV. CANNIBALIZATION ACTIVITY BY MAJOR FLEETS FOR THE F-14A AND S-3A AIRCRAFT

A. INTRODUCTION

This chapter will consist of two major sections. The first section will deal with F-14A and S-3A cannibalization activity compared between the Naval Air Forces U.S. Atlantic Fleet (NAL) and the Naval Air Forces U.S. Pacific Fleet (NAP). Both of the major type commanders of these forces are responsible for the overall performance of all fleet aircraft, fleet support aircraft and aircraft carriers in their respective fleets. This comparison will be done using the measurement methodology described in Chapter II.

The second section of this chapter will interpret the comparison data presented in the first section and explain the significant disparities that exist between the two fleets flying the same aircraft, in the same carrier environment, operating under the same Naval Aviation Maintenance Program.

1. Cannibalization Removals Per 100 Flight Hours

In Chapter II it was shown that cannibalization removals and flight hours had a definite relationship and correlation for the F-14A and S-3A aircraft navywide; that is, flight hours was shown to be a fairly strong predictor of cannibalization removals with a coefficient of determination of .769 for the F-14A and .824 for the S-3A and

with t-statistics well outside of the 95% confidence region. The data will now be seperated into that associated with NAL and with NAP.

Figures 25 and 26 display NAL and NAP cannibalization removals per 100 flight hours for both the F-14A and S-3A aircraft.

In the case of the F-14A aircraft a regression analysis of cannibalization removals, Y, per flight hour, X, by fleets provides a coefficient of determination of .830, a t-statistic of 6.98 and a regression equation of $Y = -54.19 + 0.648X$ for NAP. The NAL fleet has a regression equation of $Y = 75.02 + 0.385X$ with a .556 coefficient of determination and a t-statistic of 3.53.

A least squares regression analysis of the S-3A aircraft provides the following results. The NAP S-3A squadrons produce a regression equation of $Y = -52.89 + .400X$ with a t-statistic of 17.67 and a coefficient of determination of .969, while the NAL S-3A squadrons yield a regression equation of $Y = 133.88 + .317X$ with a t-statistic of 5.40 and a coefficient of determination of .745. Figures 27 and 28 plot the F-14A and S-3A regression analysis data.

Both regression analyses indicate that NAP cannibalization is significantly more flight hour dependent than NAL cannibalization.

Why flight hours is a much more significant factor in NAP than in NAL must be answered before any major cannibalization policy can be made and this will be dealt with in section B of this chapter.

FIGURE 25

Cannibalization Removals Per 100 Flight Hours

F-14A NAL and NAP

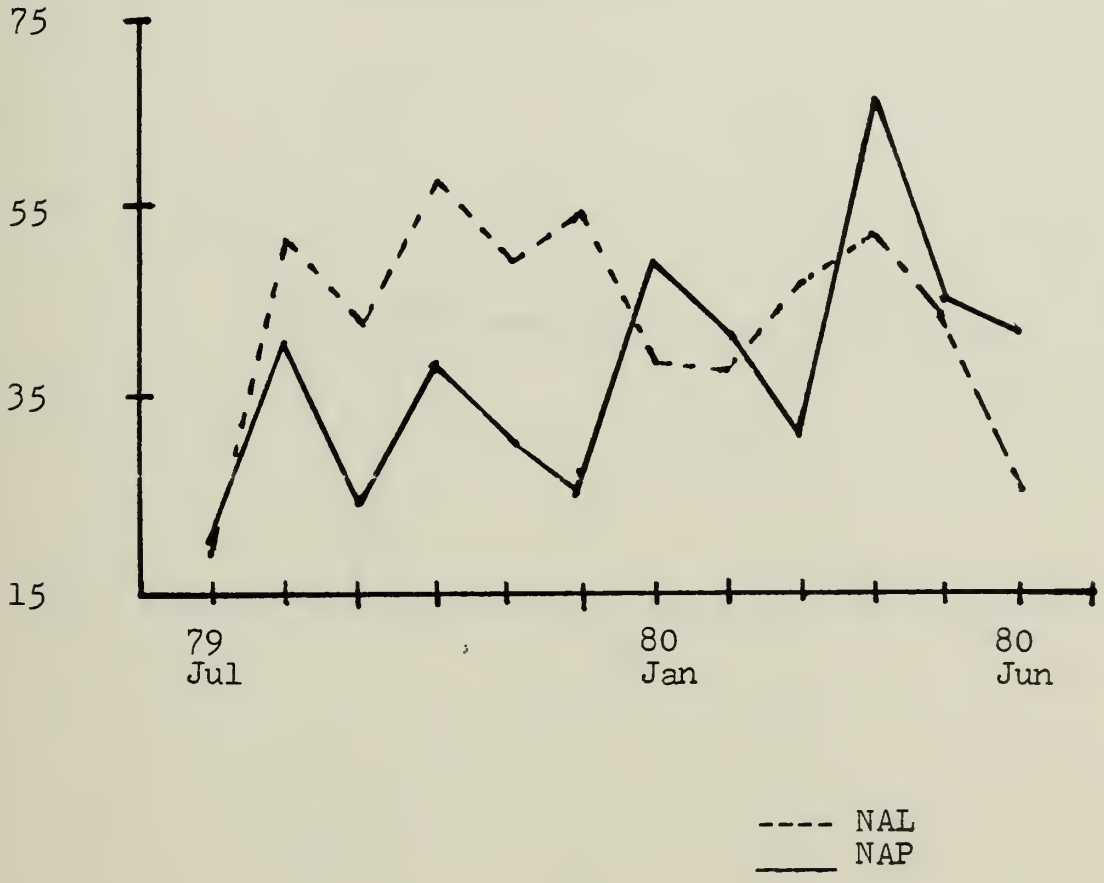


FIGURE 26

Cannibalization Removals Per 100 Flight Hours

S-3A NAL and NAP

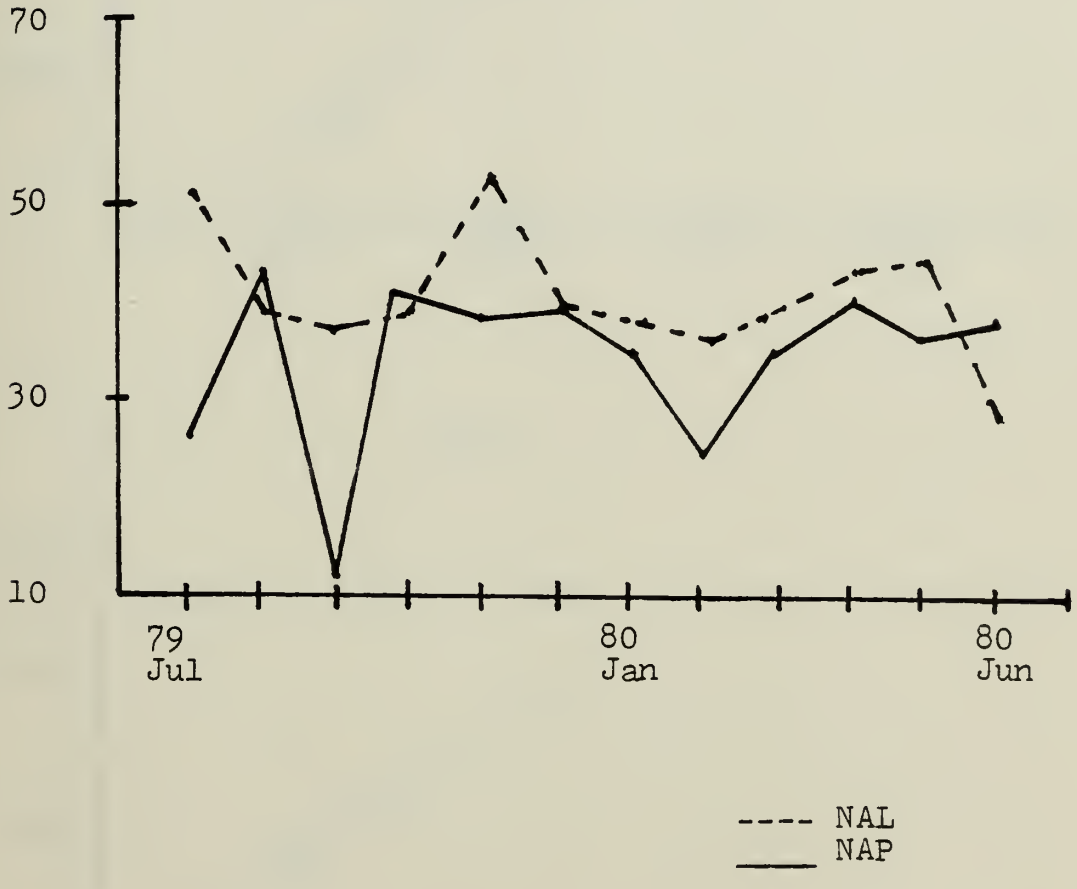
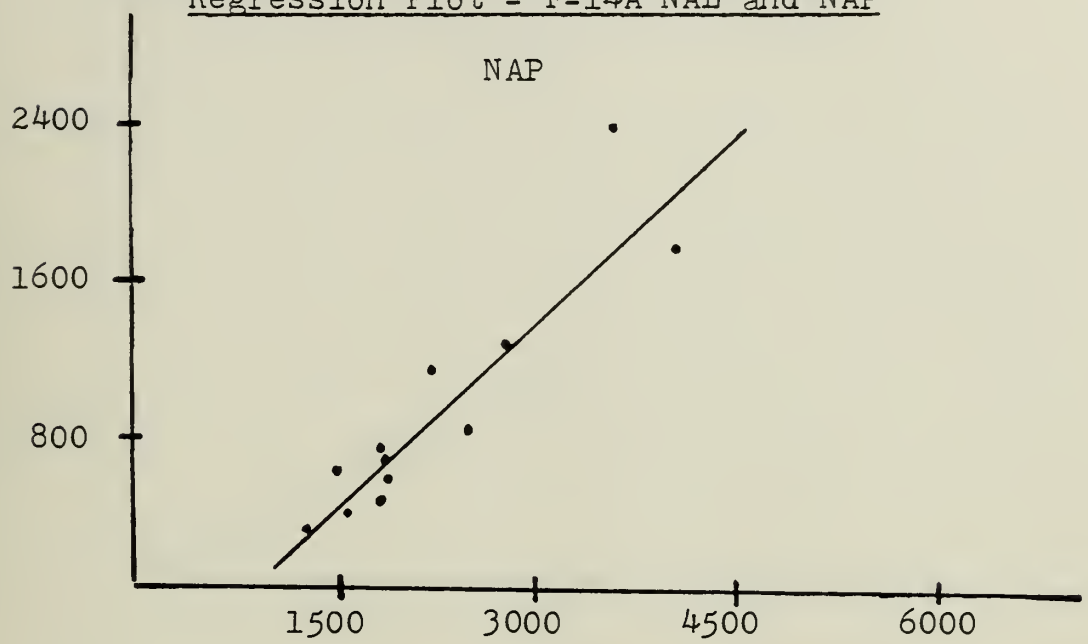


FIGURE 27

Cannibalization Removals Per Flight Hour
Regression Plot - F-14A NAL and NAP



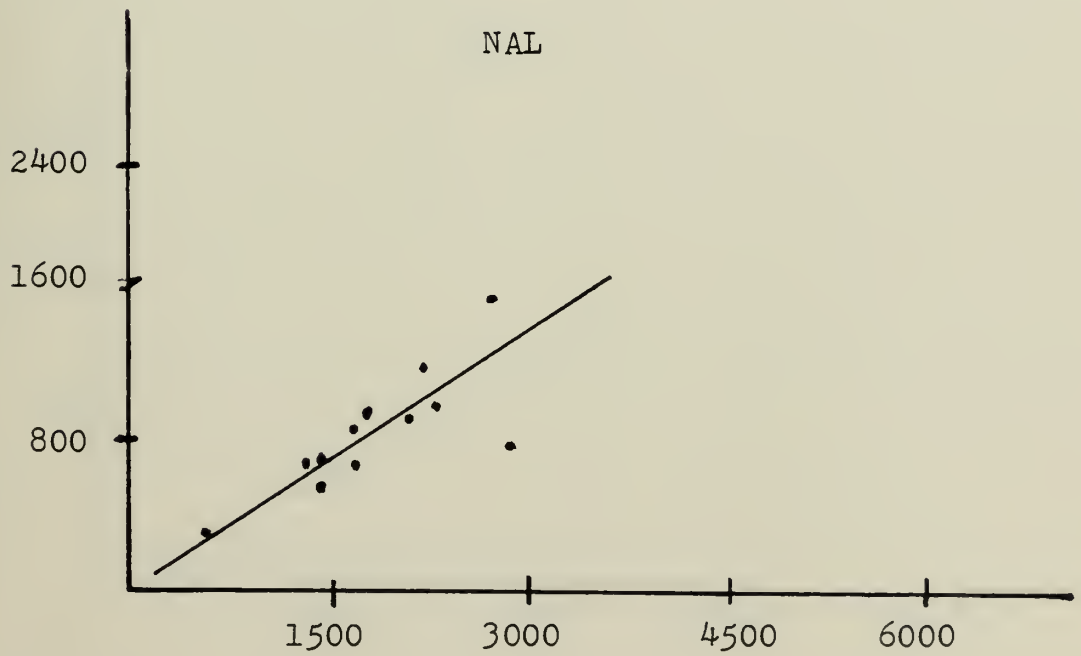
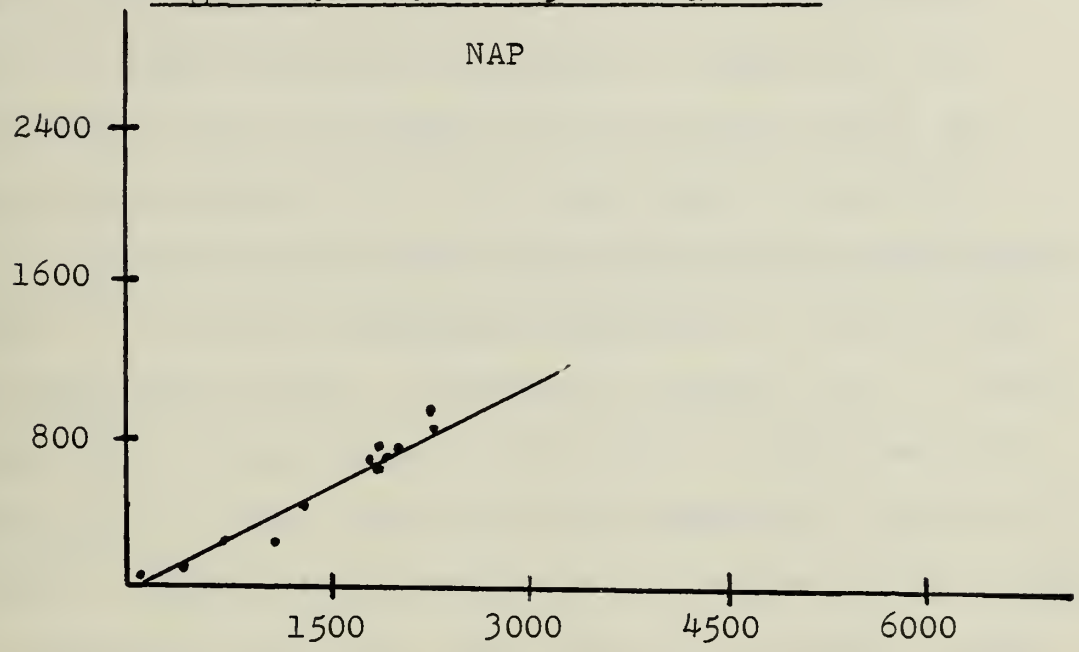
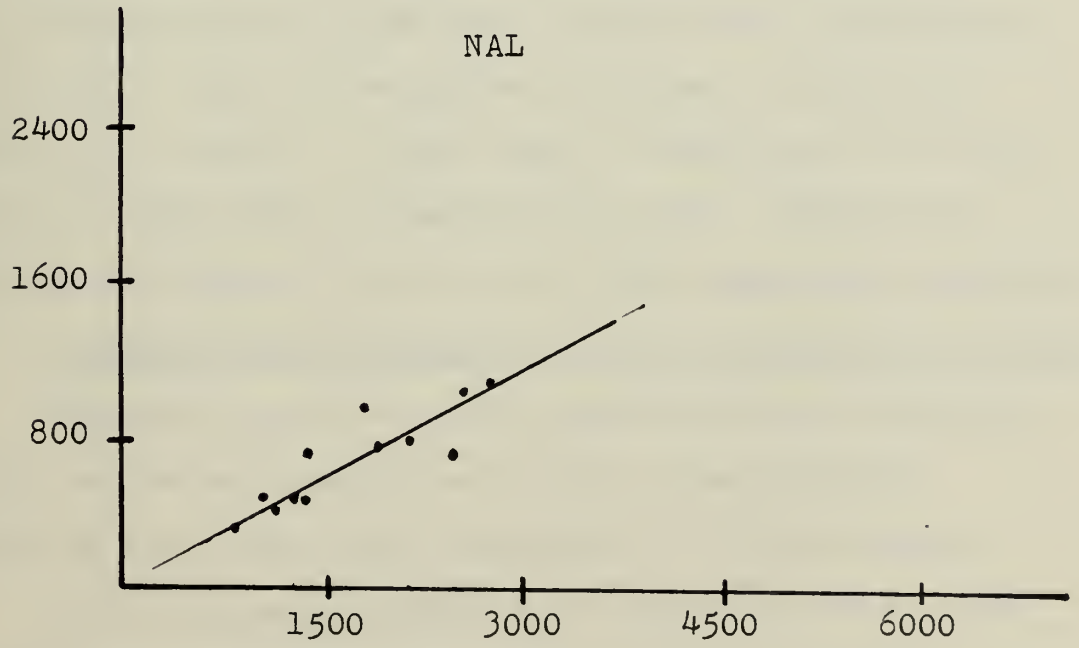


FIGURE 28

Cannibalization Removals Per Flight Hour
Regression Plot - S-3A NAL and NAP





2. Cannibalization Removals to Total Maintenance Removals

The next major cannibalization methodology to be explored as it relates to both fleets is cannibalization removals to total maintenance removals. Figures 29 and 30 illustrate this methodology for both fleets using the F-14A and S-3A aircraft over the time spand of the data.

A least squares regression analysis of cannibalization removals, Y, to total maintenance removals, X, for the NAP F-14A squadrons provides a regression equation of Y = -381.3 + .449X, with a t-statistic of 12.40 and a coefficient of determination of .938. The NAL F-14A regression equation is Y = 344.9 + .223X, with a coefficient of determination of .489 and a t-statistic of 3.09. Using the S-3A aircraft, the NAP regression equation was calculated to be Y = -21.9 + .375X, with a t-statistic of 24.78 and a coefficient of determination of .983. NAL S-3A squadrons provided a regression equation of Y = 20.73 + .356X, with a coefficient of determination of .905 and a t-statistic of 9.81. Figures 31, 32 and 33, 34 display the F-14A and S-3A regression data plots.

3. Cannibalization Manhours to Total Maintenance Manhours

Figures 35 and 36 display cannibalization manhours to total maintenance manhours for the F-14A and S-3A aircraft by fleet over the time spand of the data base.

A least squares regression analysis for NAP F-14A aircraft yields a regression equation of Y = -1067.4 + .0608X, with a coefficient of determination of .807 and

FIGURE 29

Cannibalization Removals to Total Maintenance Removals

F-14A NAL and NAP

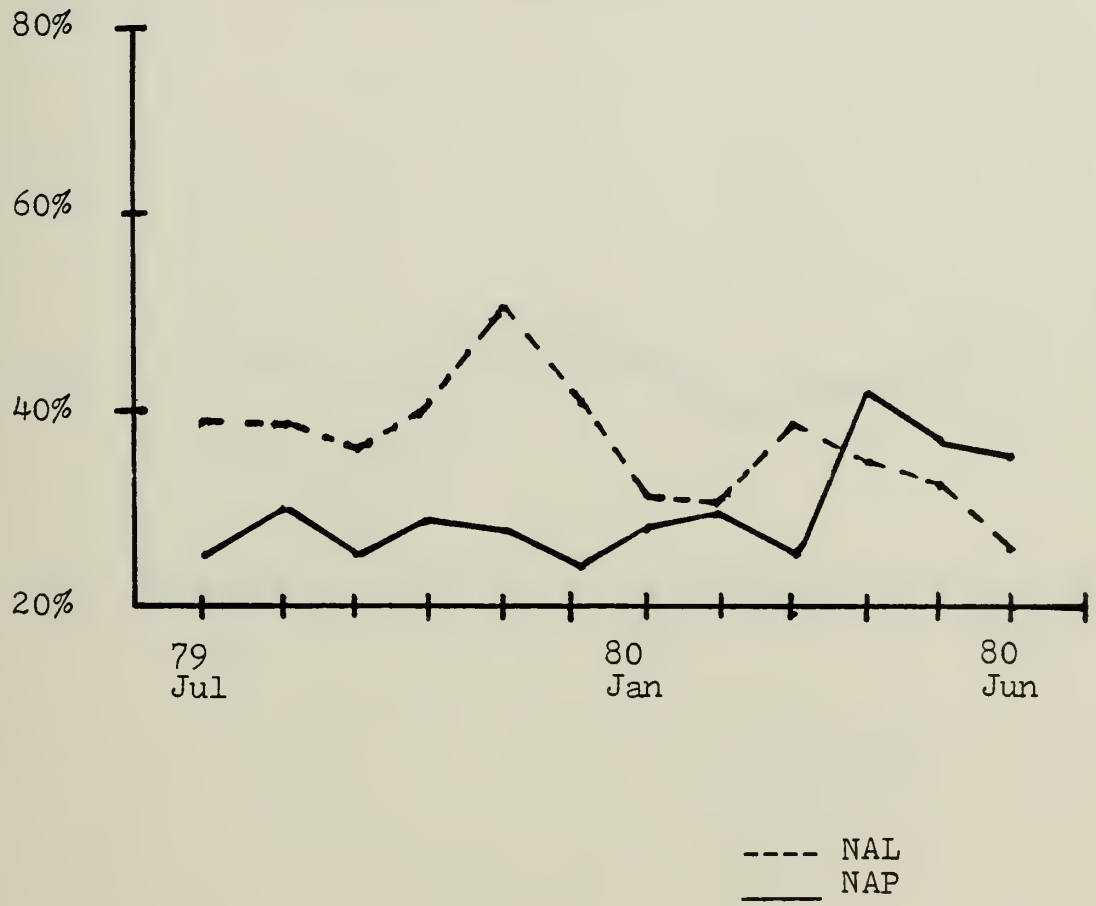


FIGURE 30

Cannibalization Removals to Total Maintenance Removals

S-3A NAL and NAP

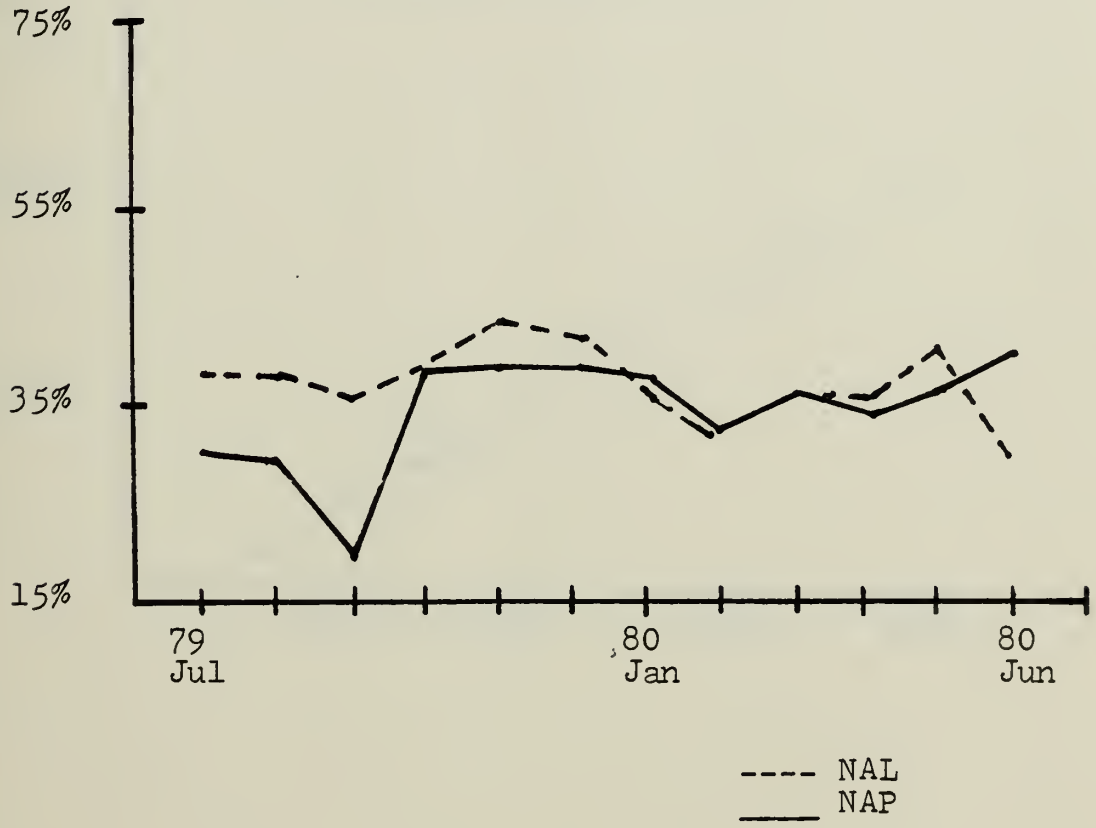


FIGURE 31

Cannibalization Removals to Total Maintenance Removals

Regression Plot - F-14A NAP

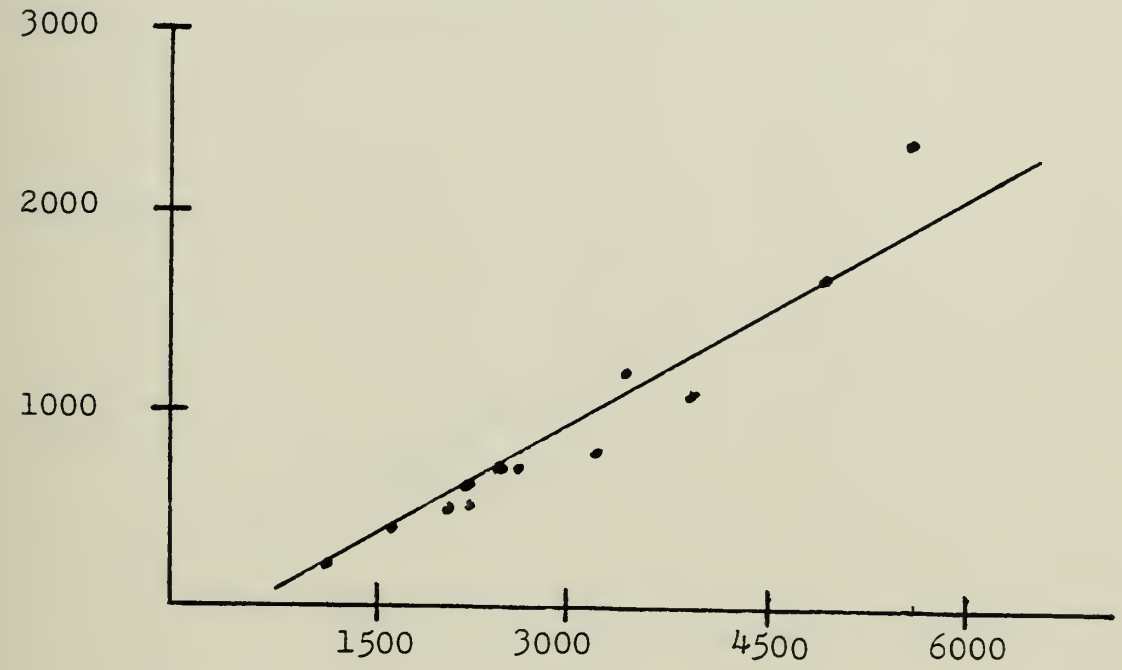
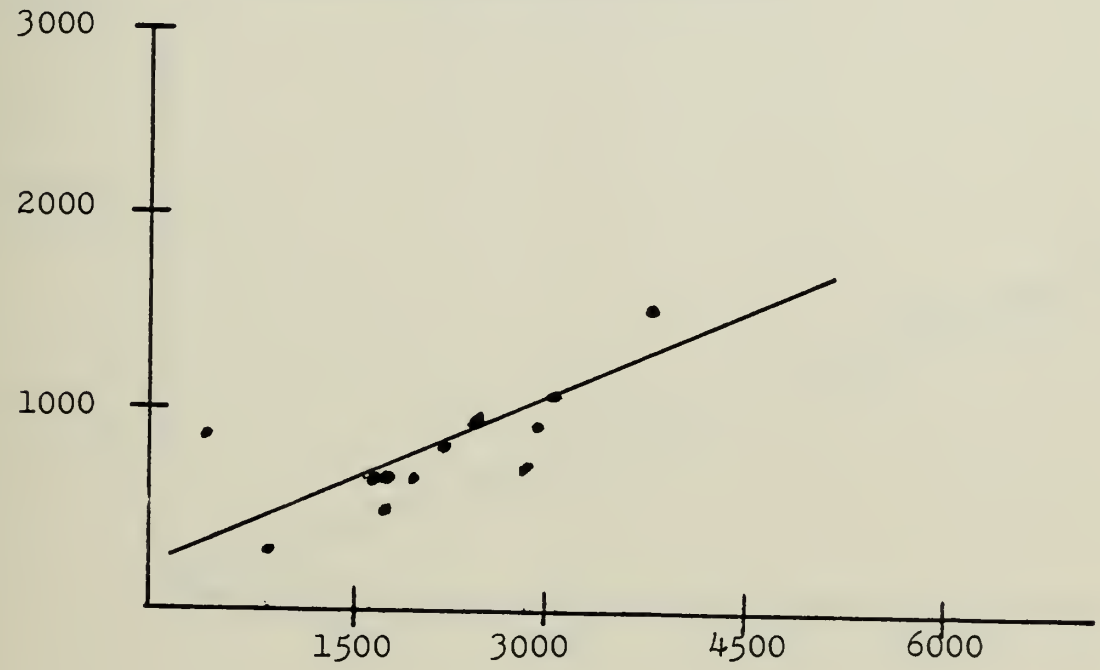


FIGURE 32

Cannibalization Removals to Total Maintenance Removals

Regression Plot - F-14A NAL



risk avoidance as the only reasons left to explain the fleet dichotomies. By examining Tables I and II for the F-14A and S-3A aircraft it becomes apparent that there is a large disparity in cannibalization removals per flight hour between NAL and NAP.

In the case of NAP and the F-14A aircraft, the regression data for cannibalization removals per flight hour indicates that 83.0% of the monthly variance in cannibalization removals is explained by flight hours for NAL only 55.6% of the monthly variance in cannibalization removals is explained by flight hours. Using the S-3A aircraft gives much the same results. NAP S-3A aircraft indicate that 96.6% of the monthly variance in cannibalization removals is explained by flight hours where as NAL S-3A aircraft only explained 74.5% percent of monthly cannibalization removal variance with flight hours.

Both regression analyses indicate that NAP cannibalization is significantly more flight hour dependent that NAL cannibalization, but what is driving this difference?

Chapter III of this thesis concluded that material shortages and cannibalization activity have little or no relationship, but a higher material shortage rate will create more risk of a stockout and may drive a squadron to cannibalize to avoid risk. In the case of both aircraft the fleet with the most cannibalization removals also has the highest average NMCS rate. Both fleets may be cannibalizing to minimize risk, but the small difference in NMCS rate does not appear to explain the significant differences in cannibalization removals per flight hour.

The only reason for cannibalization remaining to explain the different cannibalization profiles is supply response time. Table III lists the top ten F-14A navywide cannibalized components by fleet and average supply response time from July 1979 to June 1980.

From this table, it is apparent that NAL drives the navywide top ten cannibalization list for the F-14A. In every case, NAL has many more cannibalization removals than NAP. Even more significant is the fact that the average supply response time for NAL is immensely longer than the average supply response time for NAP. This data supports the conclusion that NAL cannibalizes due to supply response time delays much more than NAP in the case of the F-14A. (S-3A data of this detail was not available)

The top ten navywide cannibalization removal list accounts for 25.8% of all NAL cannibalization, 13.5% of all NAP cannibalization and almost 20% of all F-14A cannibalization. NAL's top ten cannibalized F-14A items total 2586 while NAP's top ten list is only 1526. The difference between NAL and NAP is 1059 items. This difference between NAL and NAP, on the top ten items list alone, explains most of the difference in the mean rate between NAL and NAP when measuring cannibalization in terms of flight activity. For example, if NAL were to reduce its cannibalization by 1059 items (the difference between NAL and NAP on the top ten list) the following profile would develop:

TABLE III

Top Ten F-14A Cannibalization List

Components	Navy	Cannibalization Removals		Average Supply Response Time In Days	
		NAL	NAP	NAL	NAP
Antenna Controller	604	382	222	7.46	3.36
Radar Receiver	544	336	208	7.92	3.52
Digital Display	455	247	208	9.42	5.81
Signal Computer	413	238	175	5.62	5.11
Antenna	400	270	130	10.11	5.11
Signal Convertor	376	246	136	6.40	1.23
Inertial Measurement	366	190	176	9.97	5.20
AICS Programmer	274	206	68	7.42	2.84
Control Air Data Computer	249	162	87	7.06	5.94

TABLE IV

F-14A

	NAL (now)	NAL (after reduction)	NAP
Cannibalization Removals Per 100 Flight Hours (yearly mean)	45.3	40.5	41.1
Cannibalization Removals Per Sortie (yearly mean)	.74	.66	.63
Cannibalization Removals to Total Maintenance Removals (yearly mean)	38%	32%	32%

This new profile explains the flight activity dichotomies that exist between NAL and NAP, as well as the dichotomy that exists between NAL and NAP when measuring cannibalization removals to total maintenance removals. Considering the new figures for NAL that occur, if NAL reduced cannibalization by the difference between NAL and NAP on the top ten item list all measurement criteria in Table IV become almost identical. This suggests that NAL cannibalizes to minimize supply response time delays.

This difference in supply response time between NAL and NAP on the top ten cannibalized item list may also explain the cannibalization manhour differences between fleets.

All of the top ten F-14A cannibalized items are very easy to cannibalize in that they require very few manhours per component to cannibalize. By examining cannibalization manhours to total maintenance manhours, cannibalization manhours per cannibalization removal and cannibalization manyears in Table I and II, it becomes apparent that in the case of both the F-14A and S-3A aircraft NAL has a much better cannibalization profile than NAP using manhour methodologies. By cannibalizing items that require very few manhours per component to cannibalize, NAL develops a cannibalization profile where cannibalization manhours as a measurement criterion, shows that NAL expends less manhours in an absolute and percentage sense cannibalizing.

V. SHOULD MAJOR POLICY MAKERS WORRY ABOUT CANNIBALIZATION?

A. INTRODUCTION

Cannibalization is simply an expression of a failure somewhere in the logistic system. What causes that failure or how much it costs to fix the failure is what major policy makers should worry about, not the fact that a component was cannibalized from one aircraft to another. In this chapter, cannibalization as it relates to the logistic system will be explained in an effort to determine if cannibalization is an evil maintenance practice to be avoided at any cost or if cannibalization is a viable logistic alternative.

B. COST OF CANNIBALIZATION

Chapter II of this thesis pointed out that the entire U.S. Navy spent 53.12 manyears cannibalizing the F-14A and S-3A aircraft between July 1979 and June 1980.

By dividing 53.12 by the number of F-14A and S-3A squadrons (28) an average of 1.89 manyears per squadron was spent cannibalizing. The question that must be answered is, are the 1.89 manyears per squadron spent cannibalizing in excess of total maintenance manyears available to a F-14A or S-3A squadron or do the F-14A and S-3A squadrons not use all available manyears to begin with?

By dividing the 53.12 manyears into its basic components, a much different view of the cost of cannibalization in terms of manyears developes. For example, the S-3A aircraft spent 21.5 manyears cannibalizing 14,596 components. This means that because there are 12 S-3A squadrons, the average squadron spent 1.79 manyears cannibalizing.

The F-14A aircraft presents much the same picture. All navy F-14A cannibalization was 31.62 manyears for the period of July 1979 to June 1980 (this equates to 1.97 manyears per squadron spent cannibalizing). Of the 16 F-14A squadrons 14 are seagoing and two are replacement training squadrons. A seagoing F-14A squadron has allowance for 168 organizational level maintenance technicians. With the typical 80% manning that is present navywide, this equates to 134 maintenance personnel per squadron. One hundred and thirty four men per squadron times 14 squadrons equates to 1876 manyears of maintenance for the seagoing squadrons. All recorded maintenance on the F-14A, including the two training squadron manyears, only equates to 650 manyears documented between July 1979 and June 1980. Clearly, 31.62 manyears is very insignificant when compared against 1226 manyears available for maintenance that is not utilized. F-14A and S-3A cannibalization does not cost extra manyears. It is merely work that can easily be handled by existing manpower.

Where manyears may have an impact on a squadron is at the workcenter level. If one workcenter is doing most of the

cannibalization then cannibalization may indeed have an adverse impact on workcenter manpower. For example, if one workcenter accounts for the majority of cannibalization in a squadron, there may well be a manpower cost associated with cannibalization. In the case of F-14A aircraft for example, seven of the top ten navywide cannibalization list components belong to one workcenter. This workcenter could very possibly be working more manyears than available by working normal time.

C. ALTERNATIVES TO CANNIBALIZATION

Cannibalization delivers to the maintenance manager a timely component that is ready for flight with a minimum amount of effort. Cannibalization discounts logistic system failures and allows the maintenance manager to work in an environment of low risk. Cannibalization can maximize readiness, help meet most, if not all, operational commitments placed on a squadron and discounts supply response time delay problems. In fact, cannibalization allows aircraft that have maintainability design features to utilize those engineered features to their fullest extent possible by not waiting for a one hour supply response time delay.

The only alternative to cannibalization, if readiness and operational commitments remain the same, is a logistic system that works with much better accuracy than is now present. The only problem is that to fix the logistic system to the point where cannibalization is reduced by 20% may

cost so much more than cannibalization does that from a cost-benefit standpoint it would be like throwing money away. If the average manyear of labor cost as much as $100,000.00 then a 20% reduction in cannibalization by all F-14A and S-3A squadrons would only equate to 1.06 million dollars saved. Using an F-14A squadron as an example, 1.97 manyears times $100,000.00 times 20% is only $39,400.00.

If this savings of $39,400.00 is spent to reduce risk of stockout by buying more spare parts or improving supply response delays it is not going to buy very much.

Thus, from a cost standpoint, cannibalization is much cheaper than a new logistic system. The only alternatives are to fix all logistic reasons for cannibalization or procure an aircraft that is 100 percent reliable so that a logistic system is not needed.

VI. CONCLUSIONS

This thesis presented an analysis of cannibalization as it affects the F-14A and S-3A aircraft navywide and by major type commander. The objectives of this thesis were to present cannibalization measurement methodologies, why squadrons cannibalize, a comparison by major fleets and to determine if cannibalization is in fact a viable logistic alternative.

From this analysis of cannibalization it was learned that cannibalization is clearly a function of flight activity. In fact, 76.9% of the monthly F-14A and 82.4% of the monthly S-3A cannibalization variance is caused by the monthly variation in flight hours. It was shown that the number of sorties or flights by a given type aircraft is a much better predictor of cannibalization activity than the number of flight hours on an aircraft. Sortie activity accounts for 82.5% of the F-14A and 90.3% of the S-3A monthly variance in cannibalization removals. Clearly, if one has to measure cannibalization in terms of flight activity, cannibalization removals per sortie is the best measure.

The analysis of why squadrons cannibalize pointed out that one could be 100% effective at meeting NMCS goals, and not even dent the amount of cannibalization that takes place. However, cannibalization is an expression of a failure

somewhere in the logistic system. The high tempo of carrier operations that requires maintenance managers and technicians to repair a returning aircraft in less than 30 minutes with an aircraft that was designed for component removal and replacement in less than 15 minutes, and a logistic support system based on a one-hour supply response time is where the problem begins. Clearly, if cannibalization is to be reduced by 20%, the highest payoff potential is in reduced supply response time.

The single biggest lesson to be learned from this analysis of cannibalization is the fact that the act of cannibalizing a component is not bad, but the double maintenance manhours that occurs is. We ask our maintenance technicians to expend double manhours because as maintenance and logistic managers we cannot make the logistic system serve us properly. Thus, the 20% reduction called for by the Chief of Naval Operations should be in manhours.

Cannibalization should be utilized, but tempered with sound common sense until the logistic system problems that created it can be corrected. However, the cost of fixing the logistic system failures may far exceed the cost of the manyears spent cannibalizing now.

If a manyear of labor cost the U.S. Navy as much as $100,000.00, then the total annual cost of all F-14A and S-3A cannibalization would only be 5.3 million dollars. This amount of money would not do much to help fix a logistic

system problem when you could only buy two or three spare components per aircraft carrier before your money ran out. However, it may make a big dent in the supply response time problem if it were spent on computers to speed up the manual issue of replacement components.

A 20% reduction as called for by the Chief of Naval Operations would reduce the dollars available to help fix the logistic system from 5.3 million to 1.06 million. Clearly, 1.06 million dollars would do very little in helping 28 squadrons reduce cannibalization.

Cannibalization should and can be minimized and some reduction is a sound achievable goal. But, why 20%? Why not 15% or 25%? What is so magic about a 20% reduction? This reduction should be in manhours, not items cannibalized. With this in mind, the author recommends the following actions:

1. Measure cannibalization in terms of manhours.

2. If cannibalization must be measured in terms of flight activity, use sorties rather than flight hours.

3. Make supply response time instead of not mission capable supply rates (NMCS) the primary measure of supply effectiveness.

4. Expend resources reducing supply response time delays rather than increasing stock levels by:

a. Reducing the naval aviation maintenance program supply response time standard to 15 minutes, so engineered maintainability design criterion can be fully utilized without cannibalization;

b. Relocate as many high demand, easy to remove and replace components as space allows to the flight deck to reduce issue delay time;

c. Automate the DD-1348 and Technical Research Sections of the Supply Response Center to allow for decreased paper work time on material issues;

d. Rearrange aircraft carrier store rooms so components that meet the maintainability design criterion of 15 minutes to remove and replace are stored to minimize their distance from point of demand.

5. Temper any cannibalization monitoring program with sound common sense. Remember it is the acquisition and policy setting process that gives maintenance managers, supply officers and naval aviators an aircraft to repair in thirty minutes with a supply system based on one-hour response time and an aircraft designed which has components which can be removed and replaced in less than 15 minutes.

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